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Frustrated Fertility: A Population Paradox

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Frustrated Fertility: A Population Paradox

By Joseph A. McFalls, Jr.

Abstract—This *Bulletin* examines the causes of subfecundity—the diminished ability to reproduce—and its effect today and in the past on the fertility, or actual reproductive performance, of individuals and, hence, populations. By definition, all real populations are subfecund since all experience some degree of involuntary biological factors affecting coitus, conception, or the ability to carry a conceptus to a live birth which reduces their fecundity below the estimated biological population maximum of 15 children per woman. Affecting both men and women, these factors fall into five categories: genetic factors such as blood group incompatibilities and inherited sickle cell anemia or diabetes; psychopathology, including psychic stress and behavioral disorders (e.g., drug and alcohol abuse); infectious diseases such as gonorrhea, malaria, tuberculosis, and post-abortion infection; malnutrition, including the chronic undernutrition of the Third World and the overnutrition of developed societies; and hazards posed by increasing amounts of radiation and toxic chemicals in the environment. Reducing subfecundity requires improved living conditions, avoidance of or protection against known hazards, and adoption of medical advances which now can help 40 to 60 percent of subfecund couples. Eliminating subfecundity would affect fertility most in non-contracepting societies, particularly the band of Central African countries where involuntary childlessness now ranges up to 50 percent. But even in the U.S., fertility would certainly rise among the 15 percent of couples now estimated to be involuntarily childless and the 10 percent who have fewer children than they want, and among disadvantaged groups, and teenagers.

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Photo Wide World

Louise Brown, born July 25, 1978, in Oldham, England, was the world's first baby to be born after being conceived in a laboratory outside her mother's body. Medical advances can now help 40 to 60 percent of couples who have trouble producing the children they want, but reducing subfecundity also requires tackling such conditions as infectious disease, poor nutrition, psychic stress, and environmental hazards which contribute to its widespread prevalence around the world.

Frustrated Fertility: A Population Paradox

By **Joseph A. McFalls, Jr.**

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On July 25, 1978, in Oldham, England, a baby girl, Louise, was born to Gilbert and Lesley Brown. The birth was announced in headlines throughout the world and reporters pressed in on the small hospital to get pictures of Louise and statements from her parents. The reason for this extraordinary interest in the birth of one child was that Louise Brown was the first baby in history to be conceived outside her mother's body. Lesley Brown, unable to conceive because her fallopian tubes are missing, underwent a simple operation to remove several ripened eggs from her ovary. These eggs were fertilized in a laboratory dish with a preparation of her husband's sperm and, after several stages of cell division, a suitable embryo was implanted in Mrs. Brown's uterus. Louise was born by Cesarean section 37 weeks later, premature but evidently healthy and normal.

For this brief period the world's attention was diverted from the more familiar demographic topic of runaway population growth to a rarely discussed problem which nonetheless affects a sizable minority of the world's population—subfecundity. Subfecundity is any level of reproductive ability which is less than maximum. For the Browns and millions of other couples it is a curse that prevents them from having a child or the number of children they desire. But for a substantial minority of the world's population it is a blessing in that it limits the number of unwanted births. Thus subfecundity has a significant impact on the fertility of many individuals, and hence on population fertility.

This *Bulletin* considers the effect of population subfecundity on the fertility of present and historical societies and examines some of its more important causes. But first it is necessary to clarify important terminology and expand on what is meant by subfecundity.

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Dr. McFalls is grateful for the helpful comments received in the preparation of this Bulletin *from Jean van der Tak and Dr. Louis M. Hellman of the Population Reference Bureau.*

Defining Subfecundity

Fecundity is used here to mean reproductive ability as opposed to **fertility** which denotes actual childbearing. **Subfecundity** refers to the diminished capacity to reproduce. The most severe form of subfecundity is **infecundity,** the total inability to reproduce both presently and in the future. Infecundity may develop in an individual who in the past was fecund and perhaps even had children. A **subfecundity factor** refers to a cause of subfecundity such as disease or psychic stress.

Subfecundity results from impairment of any of the biological aspects of reproduction--coitus, conception, and the ability to carry a conceptus to a live birth. **Coital inability** is defined as the inability to perform normal heterosexual intercourse. It afflicts both men and women, especially the former, and can be chronic or temporary. **Infertility** is defined as the diminished ability to conceive or to bring about conception. Thus infertility refers here only to conceptive difficulties, although the term has been used elsewhere to cover pregnancy loss and even coital problems as well. **Sterility** is the *complete* inability to conceive or bring about conception. It is simply the lowest point on the infertility continuum. Infertility is an important cause of subfecundity in both men and women, and like coital inability, can be chronic or temporary. Finally, **pregnancy loss** refers to the involuntary termination of a pregnancy before a live birth. It includes spontaneous abortion (miscarriage), late fetal death, and stillbirth, but not induced abortion or neonatal mortality (death in the first four weeks of life). While primarily a form of female subfecundity, pregnancy loss is partly due to defective sperm and thus is also a form of male subfecundity. **Perinatal mortality,** a joint term for late fetal mortality and neonatal mortality, is also discussed with respect to the findings of studies which do not differentiate between these two components.

Although both men and women can be subfecund, most specialists in this field prefer to focus on the couple because the couple's subfecundity is frequently the result of several defects, often minor, in both partners. Also, two otherwise fecund individuals may form a subfecund couple due to various biological incompatibilities. A woman, for instance, may produce antibodies against her partner's sperm. Napoleon and Josephine were a classic case of such "situational subfecundity"; both were fertile with another mate but were unable to have children together.

A population's fecundity is the average fecundity of its individual members. Individual fecundity varies widely. Some individuals are unable to have children throughout their lives. Others are superfecund, the world record for fecundity (and fertility) being held by a 19th century Russian woman who reputedly produced 69 children in 27 pregnancies. Although this claim is suspect, there is no doubt that some women have given birth to more than 30 children. Raymond Pearl, for instance, mentions one woman who had 32 children by age 40.[1] Thus individual fecundity varies from zero to more than 30 children. Maximum population fecundity falls somewhere between these extremes. It is impossible to calculate actual population fecundity, but by splicing together the highest age-specific fertility rates on record and considering other hypothetical models, most authorities estimate maximum population fecundity to be about 15 children per woman.[2] In other words, a population of women who engaged in regular sexual intercourse from menarche to menopause without using any form of birth control would, under the most favorable reproductive circumstances, average about 15 children per woman. A population is subfecund to the extent that it is biologically incapable of achieving this roughly estimated average. Since no population enjoys completely favorable reproduc-

tive circumstances, some causes of subfecundity are present in all real populations, and hence all are subfecund according to this definition. It is their relative ability to achieve this standard, however, that is pertinent here and of demographic significance.

The actual fertility of almost all populations ranges from one to eight children per woman, with about four being the worldwide average in 1978. Of course, subfecundity accounts for only some of the difference between this performance and the 15-child estimate of maximum fecundity. As demographers Kingsley Davis and Judith Blake pointed out in a classic article,[3] besides subfecundity, a society's fertility level is also determined by various forms of birth control and by the fact that much of individuals' reproductive period is spent without regular coital activity. One of the basic tasks of fertility studies is to determine the relative impact of these subfecundity, birth control, and "mate exposure" factors which Davis and Blake characterize as "intermediate variables."

Population subfecundity varies widely between populations due to substantial differences in rates of coital inability, conceptive failure, and pregnancy loss, and the length of time between puberty and the climacteric in men and between menarche and menopause in women. The average length of the reproductive period, for instance, is greater in developed than in developing societies. Subfecundity also varies over time for a given population. German women at the turn of the century, for example, had a reproductive span ten years shorter than today's. On the average, they now reach childbearing age (menarche) at 12 and leave with menopause at age 52; 75 years ago, their reproductive lifetime stretched only from ages 15 to 45.

The relative contribution of male and female disorders to subfecundity differences between populations and over time is also highly variable. This is difficult to pinpoint because men's reluctance to admit responsibility for a couple's subfecundity, particularly in developing societies, means less is known about the prevalence of male subfecundity. However, experts estimate that male subfecundity accounts in whole or in part for from 20 to 60 percent of the subfecundity in various populations. In the U.S., the consensus is that men contribute to subfecundity in 30 to 40 percent of cases and women, in 60 to 70 percent.

Effect of Subfecundity on Fertility

That subfecundity is one of the major determinants of population fertility is not just deduction. Statistics reveal that it is true of all populations, even of the group thought to be reproducing closest to the maximum rate—the Hutterites, a small religious sect scattered through the Dakotas and Montana in the U.S. and the prairie provinces of Canada. Their increasing fertility from generation to generation during the first half of this century was partly due to concomitant improvements in health conditions which affect fecundity. The power of subfecundity to affect fertility is most vividly seen in essentially non-contracepting societies with unexpectedly low fertility. These populations frequently reveal extraordinarily high rates of subfecundity. Africa presents a flagrant example of this today. In parts of Gabon, Cameroon, Zaire, the Central African Empire, the Sudan, and elsewhere across Central Africa, 20 to 50 percent of women aged 50 and older have never borne children, and subfecundity is recognized as an acute problem (see map on the next page, Figure 1).

Importance in historical societies

Subfecundity has doubtless depressed fertility since the human race began

Figure 1. Subfecundity in Africa

In parts of the African countries identified on this map, 20 to 50 percent of women aged 50 and older are childless, due mainly to high rates of infectious disease.

Source: Iain, Guest, "Infertility in Africa," Special Report, *People*, Vol. 5, No. 1 (London: International Planned Parenthood Federation, 1978) p. 23. Reproduced with permission.

about one million years ago. During most of this time, the rate of population growth was scarcely above zero. For such a low growth rate to be sustained, fertility and mortality had to be roughly the same. Experts conclude that for much of world history, average life expectancy was about 20 years. To offset this mortality, women would have had to average six to seven children, that is, substantially less than the biological maximum. Birth control and "mate exposure" variables probably accounted for much of this "fertility deficit," but subfecundity undoubtedly also played an important role in curtailing fertility and holding down population growth. Indeed, Rose Frisch suggests that subfecundity may be even more important in pre-modern societies than is usually assumed, for it could also be responsible for some of the shortfall usually credited to the other factors, especially traditional forms of birth control such as abstinence and prolonged breastfeeding.[4]

Population history prior to the 18th century can be divided into two periods, one extending back to about 8000 B.C. when agriculture was introduced and the other from 8000 B.C. to the beginning of mankind. Subfecundity influenced fertility in both periods although the leading causes were probably different. Subfecundity in historical preagricultural societies may have been similar to that observed among some contemporary hunting and gathering societies. The Kung tribe of Africa's Kalahari Desert, for instance, has moderate fertility with relatively long intervals between births. This may be partly due to poor nutrition and low body weight which reduce fecundity, conditions that may have also been common in historical preagricultural societies. The village life of the agriculturalists, on the other hand, brought comparatively many individuals close together, facilitating the spread of many diseases which cause subfecundity. Also, by relying more on crops for survival, agriculturalists became more vulnerable to crop failure which led to unpredictable and catastrophic famines and the gross malnutrition that is a potent cause of subfecundity. Thus, chronic undernutrition may have been a relatively more important cause of subfecundity in the preagricultural period, and disease and starvation may have been relatively more potent in the agricultural period.[5]

This capsule description of population history glosses over the short-term variations that occurred in growth, death, and birth rates in many societies. Subfecundity also fluctuated with the ups and downs of food supply and disease.

One disease that may have had a significant impact on the fecundity and fertility of numerous historical popula-

tions is tuberculosis. Evidences of this venerable disease have been found in the skeletons of prehistoric men. It is probable that in Eurasia after 500 A.D. tuberculosis affected mortality, fecundity, and fertility as much as or more than smallpox or plague. Tuberculosis was very prevalent in Europe prior to the 20th century and may have been a significant cause of subfecundity there.[6] It has also been suggested as a prime cause of subfecundity among U.S. blacks during the latter half of the 19th and early 20th centuries.[7] Smallpox is another disease that may have considerably reduced fecundity and thus fertility, as Peter Razzell feels it did in Britain before 1850.[8] Sudden declines in the prevalence of such subfecundity-producing diseases as tuberculosis and smallpox are often accompanied by a rise in fertility as happened in Europe during the 19th century or more recently in parts of the Third World.[9]

Importance in developing societies today

Today subfecundity affects fertility more in developing than in developed societies. This is primarily due to two situations. First, in developing societies there are fewer social checks on fertility such as effective contraception and thus more fertility potential for subfecundity to negate. Second, these societies are far more exposed to powerful causes of subfecundity, particularly disease and mainutrition. This situation is compounded (and perpetuated) by the relative absence of quality health care and facilities.

Just how poor health care is in parts of many developing nations is graphically summarized in the following description written in 1974 of a health facility near Lagos, Nigeria, where one of the few known Americans to contract Lassa fever laid over while awaiting travel accommodations to the U.S.:

"The Pest House was a crumbling building set aside for contagious diseases, with rough plaster walls and the inevitable corrugated tin roof. . . . There were no fans or screens. . . . The room was dimly lit and suffocatingly hot. . . . Within minutes she became aware of the mosquitoes; hoards of them coming in through the open windows. The small sink was black with them, and with flies. There were no nets on the beds. . . . As she got into bed . . . she saw the bedbugs, wingless blood-sucking insects with a faint acrid odor. . . . A rat scurried across the floor, darted erratically back and forth, then disappeared. . . ."[10]

Bad as these conditions are, almost one billion of the earth's inhabitants, most of whom live in developing societies, still have no access to any health care at all. Rampant, untreated disease is probably the most important reason for the subfecundity which afflicts such developing societies as the band of Central African countries with unexpectedly low fertility and high proportions of childless women.

Subfecundity can have a significant effect even on the fertility of developing societies thought to have excessively high fertility. For instance, the married Yoruba women in Ibadan City, Nigeria, average about six children per woman. Yet, by age 45, 8 percent are involuntarily childless and another 25 percent have had less than four live births in a society where four or more living children is considered the ideal.[11] If this apparent subfecundity were not present, the already high fertility of the whole population would rise materially.

Importance in developed societies today

Although not as virulent or as prevalent as in developing societies, subfecundity factors are still demographically important in developed societies. Indeed, despite the fact that the major U.S. fertility surveys of the last several decades have tended to omit subfecund women, they still found extraordinarily high rates of subfecundity among their respondents. About one-third of the

married white couples of reproductive age surveyed in the 1941 Indianapolis Study[12] and in the 1955 and 1960 Growth of American Families Studies[13] were considered subfecund. Sociologist Carl Harter also classified 33 percent of a New Orleans sample as subfecund.[14] Coital inability is particularly rife in developed societies. Sex researchers Masters and Johnson estimate—conservatively, they say—that half of U.S. couples experience sexual dysfunction sometime during their lives.[15] This seems confirmed by a recent study among white, well-educated, and happily married U.S. couples, in which a startling 40 percent of the men reported difficulties with erection or ejaculation and 63 percent of the women admitted some form of sexual dysfunction.[16]

There is reason to believe that subfecundity is on the rise in developed societies. One factor is the dramatic increase in venereal disease which can seriously damage reproductive potential. Another is the widespread use of the pill and the IUD which can also cause problems for a few women who later hope to bear children. But since the majority of couples choose low fertility and are able to attain it through birth control, the impact of subfecundity on fertility is not as substantial as it is in developing societies. However, it is still important.

If subfecundity were to be eliminated in developed societies, fertility would certainly rise. Involuntarily childless couples or those who have fewer children than desired due to subfecundity would increase their fertility. Since it is now estimated that 15 percent of U.S. couples are involuntarily childless and another 10 percent have fewer children than they want,[17] such an eventuality would have a substantial impact on U.S. fertility—without even considering increases in fertility among those other subfecund couples who do not want more children and for whom subfecundity is a blessing.

Moreover, within contracepting developed societies, there are often significant subgroups not practicing effective birth control whose fertility would rise if subfecundity were not present. In the U.S. such subgroups would include lower income whites and blacks as well as teenagers. Indeed, it could be that many subfecundity factors are disproportionately prevalent among such groups. As demographer Ronald Freedman notes:

> "Health conditions and poor nutrition may affect the fecundity of the whole society or may affect the lowest stratum with special force as a result of the operation of the economic distribution system."[18]

As in the developing societies, lack of medical care is also an important cause of subfecundity among the underprivileged in developed societies. Even in the U.S. with its relative abundance of medical professionals, medical care is spotty; it is unavailable on a regular basis, for instance, to 10 million underprivileged children.

Subfecundity can also affect the fertility of high-natality subgroups in developed societies. Take the Older Order Amish, for example, another high-fertility religious group in the U.S. Recent cohorts have completed childbearing with a mean family size of 7 compared to 2.7 for comparable national cohorts. The fertility of the Amish has been increasing over the last 100 years, and childlessness has been declining. In a fascinating forthcoming article, Julia Ericksen and her associates argue that this is chiefly due to reductions in subfecundity, noting the group's willingness to take advantage of modern medical technology as soon as it appears.[19] They also observe that while the Amish have 7 children on average, the number varies greatly between families, probably due mostly to subfecundity. Even in one sample of particularly high-fertility Amish women which happened to include no childless women they were able to classify 10 percent of the women as significantly subfecund using infertility criteria alone. These women finished

childbearing with only 4.6 children on average compared to 9.4 for the sample as a whole. In short, the authors conclude that the extraordinarily high fertility of the Amish would have been still higher had subfecundity not existed.

Some might argue that most subfecund women in developed societies still have the number of children they want; it just takes them longer. In other words, subfecundity would not affect completed fertility. This position denies the reality that substantial fractions of ever-married women in developed societies are involuntarily and permanently childless and that large numbers with children can have no more. It also ignores the effect of the timing of fertility on completed family size. For example, many women in the U.S. are now postponing childbearing until their late twenties and early thirties. This gives them fewer years to achieve their desired fertility and also requires that they do so in the face of the lower fecundity characteristic of these years due to aging and accumulated subfecundity from causes such as disease. About the much-speculated-upon possibility that many U.S. women are about to try to have their quota of two children late in their reporductive careers, demographer Conrad Taeuber has commented:

"It's a pretty cloudy crystal ball. If women have these two children, we're bound to see the number of births go up. . . . But there is some reason to believe that some women will be disappointed and find they can't have these children."[20]

Subfecundity can also have important *indirect* effects on population fertility. It may influence fertility behaviorally through others of the Davis-Blake intermediate variables, reducing, for instance, the chances of marrying or maintaining a stable sexual union.[21]

It can also indirectly affect population fertility by influencing the timing of early fertility. Most women are relatively subfecund until about age 17 and delays in early childbearing which sexually active adolescents might experience because of this could provide women with the opportunity to develop a lifestyle other than that of becoming the mother of a large family. Also, the presence of subfecundity during the early reproductive years can allow progress to be made toward learning effective birth control which would reduce unwanted fertility or give a woman time to consider what her reproductive goals really are and then attempt to stick by them.[22] The subfecundity produced by syphilis, for instance, can provide such a delay. Usually contracted early in reproductive life, syphilis causes high rates of pregnancy loss during the two years after first infection. However, even untreated syphilis has little effect on pregnancy outcome after this period so that a direct effect on completed fertility would be unlikely for couples with low or moderate family size desires. But the two-year respite during the peak reproductive years provided by the subfecundity gives a woman the opportunity to revise her reproductive goals.

Although not so important demographically, it is worth noting that sub-

Photo U.S. National Archives

An Old Order Amish farmer and his son. Completed families in this high-fertility religious group in the U.S. have 7 children on average compared to 2.7 for the U.S. as a whole.

fecundity can also affect fertility indirectly by influencing the timing of late fertility. Delays in second or later children can result in lower lifetime fertility. Subfecundity used to be responsible for a considerable proportion of two-family women—those who had children early, stopped childbearing for many years due to a variety of reasons including subfecundity, and then had other children who were far younger than the first group. Today, with the increased availability of induced abortion and better contraceptives, women more often forego the second family in favor of other lifestyles. If it were not for subfecundity in the middle years, many of these women, especially those who had not yet achieved their desired family size, might well have had additional children spaced close to the first set. Thus subfecundity, by altering when women are able to have their higher order children, may alter completed family size as well.

These indirect effects of subfecundity on fertility may now make the most difference in developed societies. But they were doubtless also important in historical societies and remain so in developing societies. For example, the subfecund wife cast out by a disappointed husband has been a familiar tragedy throughout history and still is in many developing societies today.

In sum, subfecundity can affect fertility directly and may also affect fertility indirectly by altering the timing of births or by acting through one of the other Davis-Blake "intermediate variables." Conversely, these intermediate variables, which have to do mostly with birth control and mate exposure, may themselves cause subfecundity and thus affect fertility in this way also. For example, Winnifred Cutler and her associates have uncovered evidence that later and less frequent intercourse is associated with subfecundity.[23] Understanding population fertility fully may take more knowledge about the complex interrelationships between subfecundity, birth control, and mate exposure. But it cannot be denied that subfecundity is a major determinant of population fertility in developed, developing, and historical societies.

Causes of Population Subfecundity

Population students know very little about the fundamental causes of subfecundity and tend to prefer concentrating on how to measure its effects. Demographers have made advances in understanding how subfecundity is evident in longer intervals between births, but there is not much research that goes beyond this to identify its fundamental causes and quantify their impact on fertility. One authority, Hansluwka, concludes:

"The gaps in our knowledge are too large to permit the construction of a reasonably plausible model of the effects of health on fertility via fecundity."[24]

What knowledge does exist permits the causes of population subfecundity to be separated into five categories: genetic factors, psychopathology, disease, nutritional deficiencies, and environmental factors. To be included in one of these categories, a subfecundity factor must fulfill two criteria: it must be capable of depressing individual fecundity and it must be able to affect a substantial proportion of a population's potentially fecund members.

Following is a brief overview of the five categories and their relationship to population fecundity.

Genetic factors

In their study of the Old Order Amish, Ericksen and her colleagues suggest that genetic or inherited factors might have been responsible for some of the subfecundity which they found since

subfecund couples tended to have subfecund parents. But this is a rare reference to a possible genetic impact on population fecundity (and fertility). Most fertility research has assumed that genetic fecundity is the same in all populations and, to judge from the Hutterites and other prolific groups, is at the high level of approximately 15 children per woman. This assumption makes sense since it is currently impossible to measure a population's genetic fecundity accurately and nongenetic factors are generally more important determinants of fecundity. But the assumption overlooks the fact that reproductive ability has a genetic component that can vary between individuals and thus presumably between populations. Some demographers do concede that some populations appear to be genetically more fecund than others but offer no explanations other than vague references to the super-fecund Hutterites having "bred out" their subfecund members.

However, specific genetic factors that can alter individual fecundity have been identified. For example, persons with many of the inherited anemias experience high rates of pregnancy loss. And two individuals with normal reproductive capacity may be subfecund as a couple because differences in their inherited ABO blood group antigens can result in fetal-maternal ABO incompatibility which brings on miscarriage. (An antigen is a substance capable of forming antibodies when introduced into the bloodstream.) Since the gene pool of one population is different from that of other populations, it is likely that genes that make up the pool, including those which are capable of influencing reproduction, will also vary between populations. Thus genetic factors can be a cause of fecundity differentials between populations.

Chromosome abnormalities. Perhaps the best-described genetic influences on fecundity are Klinefelter's syndrome in the male and Turner's syndrome in the female. Males with Klinefelter's syndrome are born with XXY sex chromosomes instead of the normal XY male sex chromosomes and females with Turner's syndrome have XO rather than the XX sex chromosomes of normal females. In both cases, affected persons are usually sterile since the male's testes or the female's ovaries scarcely exist. Klinefelter's syndrome affects about 1 in every 400 to 600 male babies, while Turner's syndrome turns up in a much rarer 1 in 5,000 female births.

Less dramatic variations in both sex and non-sex chromosomes have been pinpointed as significant factors in abnormally low sperm production which usually makes it impossible for the man to impregnate a woman. Chromosome abnormalities are also important in female infertility. They are detectable in 15 to 25 percent of women who fail to menstruate by age 18, which is called primary amenorrhea.

Length of reproductive life. A more subtle genetic influence on fecundity is aging. Studies show that human cells grown in the laboratory will divide about 50 times before dying; no matter how favorable the conditions, the cells are incapable of multiplying further. This suggests that an individual's maximum lifetime is programmed into his genes. It could be that heredity similarly influences the rate at which the human body ages and the timing of such milestones in reproductive life as menarche and menopause. There is some evidence for this. For example, age of menarche varies from girl to girl depending not only on environmental factors such as nutrition, but also on the age of menarche of the girl's mother. And the Abkhasians of Soviet Georgia in the U.S.S.R., many of whom live for 100 years or more, illustrate how reproductive life may be extended beyond "normal" limits in persons who enjoy remarkable longevity. Many of the men in this group remain potent long after the age of 70 and almost 14 percent of the women continue to menstruate after

age 55. However, there are inadequate data to judge the role of genetic factors in Abkhasian longevity. Likewise, the notion that the Abkhasians' extended reproductive span is genetically-determined, though certainly plausible, is entirely speculative at present.

Sickle cell anemia. A surprising number of genetic factors related to the red blood cell pose serious threats to fecundity. Among these are the inherited anemias—sickle cell anemia and its cousins, sickle cell-hemoglobin C disease and sickle cell-beta thalassemia. In the U.S., sickle cell anemia is found almost exclusively among blacks. About 10 percent of U.S. blacks carry one S gene for sickle hemoglobin but only about 1 in 500 inherits the sickle hemoglobin gene from both parents and thus suffers from the disease. Such persons have SS hemoglobin in their red blood cells rather than normal AA hemoglobin. This bends the cells into an inflexible sickle-like, or new-moon shape, in contrast to the round shape of a normal red blood cell, which prevents the cells from moving easily through the blood system so that they clot painfully and destructively in body joints and organs and gradually lose the capacity to carry oxygen. So far there is no cure for the condition.

Sickle cell-C disease and sickle cell-beta thalassemia are rare anemias found almost exclusively in the tropics. They can seriously depress fecundity. Pregnancy loss has been reported at anywhere from 16 to 62 percent among women with sickle cell-C disease and up to 24 percent for those suffering from sickle cell-beta thalassemia.

For the relatively more common sickle cell anemia, pregnancy loss can reach an incredibly high 57 percent. Moreover, the anemia is often exacerbated by pregnancy and the risks of maternal death are significant. Males with the disease have been noted to have low sperm counts or hypogonadism, that is, reduced function or delayed growth of the testes which produce the sperm necessary to fertilize the egg produced by a female. Another possible complication is priapism, a persistent painful erection of the penis which makes coitus impossible; surgery to correct this often leaves the patient permanently impotent.

Without exemplary medical care, 20 to 40 percent of the victims of sickle cell anemia die before reaching reproductive age. Despite this weeding out, the S gene still persists and in fact is carried by about 30 percent of persons in the many parts of Africa where malaria is endemic. This is because persons with the sickle cell trait, that is, those persons with only one gene for sickle hemoglobin, AS, stand a better chance of surviving malaria than the normal AA genotypes—some 10 to 15 percent better even in the case of the most dangerous of malaria parasites, the *Plasmodium falciparum*.

Some experts believe that this well-known relatively greater chance of survival in malarious areas of the AS genotype is not the only explanation for the high rates of sickle cell anemia seen in some parts of Africa. Could it be that the AS genotype is also more fecund and thus more fertile? This may indeed be the case. In areas where malaria is hyperendemic, AS women have slightly higher birth rates than AA women and where malaria is relatively prevalent the rates are dramatically higher—nearly one and a half times higher in one study.[25]

AS males may also have a fecundity (and fertility) advantage in malarious areas. Where malaria is rife, even adults who have built up immunity from repeated bouts usually suffer the fever and chills of malaria twice a year. In normal AA men, each of these episodes is long and intense enough to impair sperm production for one to two months. For males with the AS blood type of sickle cell anemia, malarial fevers are shorter and less intense and sperm production is not affected. Thus, while the AA male is relatively infertile two to four months of the year, the fertility of the AS male

is unaltered.

Any such fecundity (or fertility) advantage for the AS genotype disappears in non-malarious areas. In the U.S., for example, fertility histories are essentially the same for the 10 percent of black Americans who have the sickle cell trait and the vast majority who do not, with the exception of a suggested increase in rates of prematurity and low-birth-weight infants.

Red blood cell incompatibilities. In certain combinations, if a man and a woman are of different hereditary blood types, they may have trouble conceiving or the woman may suffer a miscarriage or stillbirth.

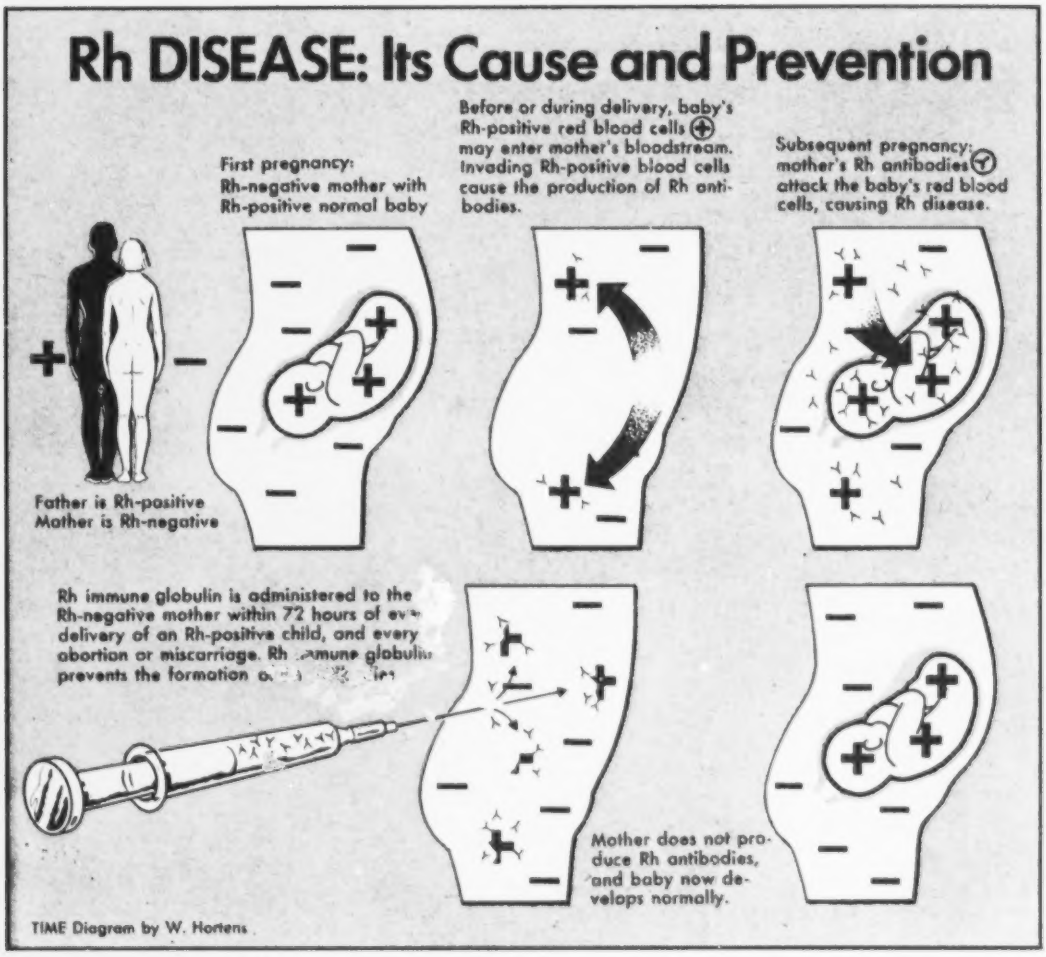
One such combination is called "ABO incompatability": the man has red blood cells which carry the blood group antigens A or B and the woman does not. Male sperm carrying the antigen may be attacked by antibodies in secretions in the woman's cervix which cause the sperm to clump together so that few or none can get through to the woman's fallopian tubes where they might fertilize the egg released when the woman ovulates. More often, however, ABO-incompatible matings result in an increase in pregnancy loss. If the fetus inherits from the father a blood group antigen that the mother does not have, antibodies against that antigen which the mother already has in her blood will enter into the fetus' bloodstream, destroy the fetus' red blood cells, and cause a spontaneous abortion. In fact, ABO incompatibility is seen in twice as many abortuses as would normally be expected. ABO-incompatibility occasionally results in stillbirths or neonatal deaths. But most of the mortality is very early in pregnancy, so early that a woman often does not realize that she has lost a pregnancy. Nevertheless, the effects on fecundity are substantial; completed family size in ABO-incompatible matings is half a child less than in compatible matings.

Males who inherit blood type A may have trouble impregnating any woman according to one study which found an excess of such blood types among a sample of infertile men, especially those with little or no sperm in their semen.[26]

The potentially harmful effects of Rh incompatibility on fecundity are much better known than those of ABO incompatibility because affected fetuses usually survive at least through a full-term pregnancy. About 85 percent of Caucasians carry the Rh (from rhesus monkeys who are all Rh positive) antigen on their red blood cells, that is, are Rh positive, compared to 93 percent of blacks and almost 100 percent of American Indians. Thus the "Rh factor" is a variable which can affect fecundity between populations.

The factor becomes a problem only when an Rh-negative woman who lacks the antigen is paired with an Rh-positive male—which is the case in about 12 percent of marriages in the U.S. Of the some 3.3 million births in the U.S. each year, about 260,000 result in the birth of an Rh-positive child to an Rh-negative mother. Some 10 percent of these 260,000 babies will suffer Rh disease to some degree.[27]

Unlike antibodies to the A and B blood group antigens which occur naturally, antibodies to the Rh antigen appear only after exposure to the antigen. If the mother is Rh negative and does not have the antigen, but her mate does (that is, he is Rh positive) and has passed the antigen to the fetus, the mother stands about a 10 percent chance of being exposed to the Rh antigen in the fetus' blood during her pregnancy. This risk falls to less than 5 percent if the pregnancy terminates early due to an abortion (spontaneous or induced). The first child is not threatened for the mother has not yet had time to become adequately "immunized" to the Rh antigen in the fetal blood and the level of antibodies against the Rh antigen is therefore low. But if an immunized mother subsequently conceives a second Rh-positive fetus her blood system, primed to react,


Rh DISEASE: Its Cause and Prevention
First pregnancy:
Rh-negative mother with
Rh-positive normal baby
Before or during delivery, baby's
Rh-positive red blood cells ⊕
may enter mother's bloodstream.
Invading Rh-positive blood cells
cause the production of Rh anti-
bodies.
Subsequent pregnancy:
mother's Rh antibodies ⊖
attack the baby's red blood
cells, causing Rh disease.
Father is Rh-positive
Mother is Rh-negative
Rh immune globulin is administered to the
Rh-negative mother within 72 hours of ev
delivery of an Rh-positive child, and every
abortion or miscarriage. Rh
prevents the formation
Mother does not pro-
duce Rh antibodies,
and baby now de-
velops normally.
TIME Diagram by W. Hortens

This diagram illustrates the cause of Rh disease and the vaccination method now most commonly used to prevent it. Reprinted by permission from TIME, *The Weekly Newsmagazine: Copyright 1973 Time Inc. All rights reserved.*

quickly starts producing antibodies which mount an attack on the fetal red blood cells. The destruction may be so severe as to cause a stillbirth or the baby may be born too early to survive more than briefly. Those who do survive can be brain damaged and all suffer with severe anemia and a jaundice-like condition.

There are now effective ways to treat this problem: by blood transfusions for the baby, either before or after birth, or by vaccinating the Rh-negative mother with a globulin which stops the production of antibodies (see diagram).

Metabolic abnormalities. There are two inherited diseases affecting a person's metabolism (ability to absorb and utilize certain types of food) which can alter reproductive potential: glucose-6-phosphate dehydrogenase deficiency and diabetes. The first results from the deficiency of an enzyme (an important substance produced in living cells) and is probably the most common of all metabolic abnormalities. It is usually a benign disease and in itself has no effect, positive or negative, on reproductive potential. But when combined with sickle cell anemia it can be a blessing

for fecundity. Sixty percent of Saudi Arabs have this deficiency disease. For those who also have sickle cell anemia, the anemia is relatively mild and the outcome of pregnancies is about the same as it is for the general population.

Diabetes, another common metabolic disease, is characterized by a deficiency in the supply of insulin secreted by the pancreas so that sugar (or glucose) in the diet is not broken down correctly. The result is a high level of sugar in the blood and urine. The condition can be controlled by diet, exercise, and regular injections of insulin, but not cured.

Diabetes significantly depresses fecundity but since it usually does not appear until after age 40, only a small proportion of the population will be affected during their reproductive years.

About 50 percent of diabetic men are impotent; this amounts to one million men in the U.S. alone. This impotence cannot be treated and is unlikely to correct itself.

Infertility is an important feature of diabetes. Before insulin was discovered in 1921 few diabetic women conceived; 50 percent were amenorrheic (had no menstrual bleeding) and another 15 percent had menstrual problems. Now, with insulin, diabetic woman have no trouble conceiving. However, diabetic men, even those treated with insulin, may develop problems with ejaculation and thus be unable to bring about conception.

Before the discovery of insulin, babies born to diabetic women suffered extremely high perinatal mortality rates. Though the rates fell steadily thereafter they remained quite high until the 1960s when diabetic pregnancies began to receive full medical supervision, at least in developed countries. Nevertheless, even with the best medical care, some 4 to 7 percent of babies carried by diabetic mothers die just before or after birth; under less favorable circumstances, the rate is much higher. Perinatal mortality rates are also a high 9 percent versus the normal 1 percent for mothers over 25 who are "gestational" diabetics, that is, diabetic only during pregnancy. (Many of these women will eventually develop full-blown diabetes.) Such women, however, make up only 2 to 4 percent of women having babies.

Given the reproductive problems which diabetics experience, how could diabetes persist at relatively high rates, especially in the days before insulin? It has been hypothesized that when food supplies are chronically short, as in the past and still today in some developing societies, persons who would develop overt diabetes in an environment of plenty might have an advantage. It has been noted, for example, that women with a hereditary tendency to diabetes begin to menstruate earlier and are more fertile. But when people with a tendency to diabetes begin to get more food, the disease develops and its negative aspects appear. Overt diabetes is becoming common in many parts of the world where rapid social change is being accompanied by substantial dietary change. Research among Kalahari Bushmen in Africa shows that their blood sugar levels are normal so long as they remain on their sparse native diet but reach levels which hint of diabetes when they are put on a high calorie diet. Diabetes is very common in Africa where social change in proceeding rapidly. In South Africa, rates among the tribal peoples still in their villages remain low, but are very high for those who have moved into the cities. When the changeover to a richer diet occurs in developing societies the genes for diabetes may be bred out if insulin is not available and the negative effects of the disease begin to outweigh its positive aspects. In the U.S., however, insulin is plentiful and its widespread use has ensured that diabetes is likely to become ever more common. The National Juvenile Diabetes Foundation has in fact estimated that, by 1980, one of every five Americans will be diabetic.

In sum, genetics can play a very important role in human reproductive potential. The hereditary anemias and metabolic anomalies can definitely influence fecundity, as can Rh incompatibility. But of the conditions noted here, ABO incompatibility appears to have the greatest potential as a fecundity depressor. Other more subtle, but potentially powerful, genetic influences which are not associated with a much studied entity such as blood group or manifested by serious disease such as diabetes will probably go unrecognized for some time. The science of genetics still has a long way to go before being able to identify all genes which influence reproductive ability and their frequency in human populations. Until then, population genetic fecundity will have to be measured by reproductive *performance* —specifically, that of the Hutterites —rather than reproductive *ability*, and possible variations in fecundity due to genetic factors will probably be disregarded.

Psychopathology

Many types of mental and behavioral disorders, or psychopathology, can lead to subfecundity by causing coital inability, infertility, and/or pregnancy loss. These include psychoses, sexual deviations, alcoholism, illicit drug abuse, cigarette smoking (a form of drug abuse classifiable as a personality disorder), and psychic stress (an amalgamation of neuroses, psychophysiologic disorders, and everyday stress).[28]

Currently, lack of data and other research problems make it impossible to measure the exact impact of psychopathology on population fecundity. Nevertheless, psychopathology is clearly an important cause of population subfecundity because it easily fulfills the two necessary and sufficient requisites: it can have a considerable impact on individual fecundity and can affect a substantial proportion of a population's potentially fecund members. In what follows, the impact of psychopathology on individual fecundity is reviewed first, followed by a discussion of its prevalence among the U.S. population of reproductive age and its effect on the fecundity of different types of populations and subpopulations.

Effect on individual fecundity

Four important aspects of the relationship between psychopathology and individual subfecundity deserve attention. The first, and most important, is that psychopathology can be involved in each of the three main components of subfecundity; it is a major cause of coital inability and of conceptive failure and pregnancy loss. In fact, psychopathology is the most important cause of coital inability, probably accounting for about 75 to 90 percent of cases. It is also the primary cause of sexual disorders that are involved in conceptive failure, such as premature ejaculation. Aside from sexual disorders, psychopathology has a whole arsenal of other mechanisms to bring about conceptive failure of which the most important is probably the frequently seen anovulatory amenorrhea (failure of a woman both to ovulate and menstruate). Psychopathology, especially psychic stress, may also be one of the main causes of pregnancy loss. And sizable proportions of alcoholic, smoking, or drug-addicted women continue their habits throughout pregnancy, seriously jeopardizing the health of their unborn child.

Understanding how psychopathology can depress fecundity is important to appreciating the powerful effects which mental disorders can have on the body. Psychopathology works through two basic mechanisms: the pharmacological and the psychosomatic. The first is not restricted to psychopathology, but simply describes physiological effects brought on by substances which a person ingests.

Naturally, a pharmacological mechanism is chiefly at work in psychopathology involving drug abuse. Two examples are the weakening of the sperm's capacity to fertilize caused by the toxic effect of alcohol on the sperm-making cells of the testis; and the higher rates of pregnancy loss experienced by smoking mothers due to nicotine-induced constriction of blood vessels, with a subsequent drop in oxygen levels in fetal tissue.

The psychosmatic mechanism through which psychopathology works to cause subfecundity is more elusive. This mechanism is operating when psychological phenomena alter the body's physiological processes. In the past, such a mechanism was considered unlikely, since psychological and physiological processes were believed to be separate and distinct. But today it is acknowledged that almost every psychological process has physiological expressions; blushing or perspiring are normal reactions to emotions, for example. But the psychosomatic mechanism involves pathological as well as normal physiological responses. Indeed, the field of psychosomatic medicine grew out of the realization that a very large percentage of human physical ailments are of mental origin. Headaches, neck pains, nausea, ulcers, mucous colitis, asthma, and allergies are just a few of the problems that are often caused by mental disorder rather than injury or disease. A sudden drop in the stock market or the termination of a love affair can exacerbate a latent peptic ulcer or reawaken a tuberculous lesion. And myriad health studies have shown that single, widowed, and divorced individuals are far more likely to fall prey to disease than the married, a demonstration of the power of social isolation and loneliness to bring about physical deterioration psychosomatically.

In the psychosomatic mechanism, the changes that accompany stress are set off and controlled by the brain and mediated by either the autonomic nervous system or the endocrine system. The autonomic nervous system is a division of the nervous system that sends electrical messages from the brain to certain organs, telling them to act in a prescribed manner. Responses brought on in this manner include contractions of the involuntary muscles that are found in most of the reproductive organs except the ovary and the testis (fallopian tubes, uterus, vagina, sperm ducts, penis, etc.), and secretory activity by the organs of secretion which are involved in the reproductive process (seminal vesicles, prostate, cervix, etc.). Thus, subfecundity may be caused by the muscular spasms that can occur in the sperm ducts of men under stress which can interfere with the sperm's motility and fertilizing capacity, or by the secretion in some stressed women of abnormal cervical mucus that is hostile

Photo: United Press International

Women who smoke cigarettes experience higher rates of pregnancy loss than women who do not. Smoking has increased considerably among U.S. women in recent decades and now amounts to 40 percent among those of reproductive age (15 to 44).

to sperm and thereby reduces the likelihood of conception.*

But the subfecundity effects which can be mediated by the autonomic nervous system are limited since the central organs of reproduction, the ovary in the female and testis in the male, are not directly responsive to nervous stimulation. Rather, as part of the endocrine system, they are stimulated by hormones from the master endocrine gland, the pituitary, a pea-sized organ located under the brain. Determining whether emotions could influence the pituitary thus became a central issue in psychosomatic subfecundity.

The link between the emotions (the brain) and the pituitary was discovered in the 1950s. In brief, higher brain centers stimulate an adjacent part of the brain called the hypothalamus, causing it to secrete chemical messages which are carried to the pituitary. The pituitary responds to these messages by releasing two hormones which activate the ovary and the testis—follicle stimulating hormone (FSH) and luteinizing hormone (LH).

In the female, FSH directs the growth each month of one of the many follicles in the ovary which contains an immature human egg. It also stimulates the follicle to produce estrogen, a hormone necessary for the maintenance of the accessory reproductive organs, such as the vagina, and the secondary sex characteristics (e.g., pubic hair). The other pituitary hormone, LH, initiates the ovulation process by which a now ripened egg bursts forth from the follicle. This follicle, though ruptured, is not functionless but instead temporarily produces a second female hormone essential to reproduction, progesterone. In the male, FSH and LH direct the testis in two important functions—the production of sperm and the production of testosterone, the male equivalent of estrogen, which maintains the accessory reproductive organs of the male (e.g., the seminal vesicles and the prostate) and his secondary sexual characteristics such as a beard and low voice.

Since the hypothalamus is the primary control site for the growth and function of the gonads (the female ovaries and the male testes), any interference with the workings of the hypothalamic-pituitary-gonadal axis can have vast repercussions on reproductive potential. Stress is capable of such interference. Under conditions of emotional stress, the functioning of the hypothalamus is altered and this ultimately affects the functioning of the ovary or the testis. Alterations in hypothalamic functioning may be responsible for the abnormal hormone levels observed in some homosexual men. And this mechanism may also play a role in the psychoses, since abnormalities in hormone levels and in the sperm-making process have been noted in schizophrenic men. But the mechanism is most frequently encountered in the neuroses, psychophysiological disorders, and everyday stress. Common examples are failures in the sperm-making and ovulation processes experienced by some stressed individuals and the cessation of menstruation associated with severe trauma, such as internment in concentration camps.

A second important facet of the relationship between psychopathology and individual fecundity is the fact that many forms of psychopathology tend to appear early in life and to persist for much of the reproductive period. This prolongation of both the disorder and any subsequent subfecundity is frequently bolstered by the tendency for psychopathology to go untreated or to be treated ineffectively.

Third, the ability of psychopathology to decrease fecundity is enhanced by

*For a brief description of the organs and processes involved in human reproduction, see Sheldon J. Segal and Olivia Schieffelin Nordberg, "Fertility Regulation Technology: Status and Prospects," *Population Bulletin*, Vol. 31, No. 6 (Population Reference Bureau, 1977).

the tendency for one form of subfecundity-producing psychopathology to cause others. Psychic stress often underlies drug addiction, for instance, and homosexuality may lead to alcoholism. Also, the fecundity of one partner of a couple may be jeopardized when psychopathology exists in the other. This is particularly relevant to psychosexual disorders; impotence in the male can lead to vaginismus (painful spasms in the vagina) in the female; premature ejaculation to female frigidity, and so forth. Indeed, if the union remains intact, it is probable that psychopathology in one partner will alter the fecundity of both members of the union to some extent.

Fourth, it is also important to note that the effect of psychopathology on fecundity may be indirect. That is, psychopathology may be causally associated with other factors that are the direct cause of the subfecundity such as disease and malnutrition. For example, psychic stress can increase the incidence, duration, and severity of tuberculosis, an important cause of subfecundity. Also, homosexuality is often associated with venereal diseases that can limit or destroy reproductive potential. And illicit drug abuse frequently leads to another cause of subfecundity, malnutrition.

Thus, psychopathology ably fulfills the first requirement of a determinant of population subfecundity, that is, it is an important cause of individual subfecundity.

Prevalence

Psychopathology can also be relatively widespread among the members of a population during their reproductive ages, the second requisite of a population subfecundity factor. Estimates of the prevalence of subfecundity-producing psychopathology in the reproductive population of the U.S. can serve as a good illustration. The following estimated percentages refer to the U.S. population aged 15 to 44.

Although virtually the entire U.S. population experiences psychic stress periodically throughout their reproductive period, and indeed throughout their lifetime, only a fraction are chronically stressed. A preliminary report of the President's Commission on Mental Health found that at any given time one-fourth of the population is experiencing psychic stress that produces varying degrees of depression and anxiety. Approximately 1 to 2 percent of the population aged 15 to 44 is psychotic, and, if homosexuality is included, substantially more than 4 percent are sexual deviates. Alcoholism claims about 7 percent of men of this age and 3 to 5 percent of women. Nearly 50 percent of American men smoke cigarettes, as do 40 percent of women. And 10 to 15 percent of the population aged 15 to 44 regularly abuses illicit drugs.[29] Although these estimates are imprecise and are not additive, since the same individual may have more than one disorder, it is clear that the fecundity of a sizable fraction of the U.S. population of reproductive age is jeopardized by psychopathology.

Since psychopathological disorders that can cause subfecundity do not invariably do so, not all those at risk are affected. With the many unknowns, it is difficult to provide even an approximate estimate of the proportion of the U.S. population aged 15 to 44 which actually becomes subfecund due to psychopathology. However, after considerable study, it is this author's judgment that an exceedingly conservative estimate would be 15 to 20 percent.

Probably the most potent psychopathological causes of subfecundity in the U.S. and elsewhere are psychic stress, alcoholism, and illicit drug abuse. All three are prevalent and have a strong effect on both male and female fecundity. Other significant causes are cigarette smoking by women and sexual deviations among men.

Population variability

The prevalence of psychopathology in general and in its specific forms varies widely between populations, between subgroups within a population, and over time. The amount of psychopathology-induced subfecundity will thus vary accordingly.

It is generally agreed that psychopathology is substantially more prevalent in developed than in developing societies. Some researchers even suggest that in modern urban societies virtually everyone suffers from some form of psychopathology. Since fertility surveys repeatedly find that 30 to 40 percent of the U.S. reproductive population is subfecund despite excellent health care and relatively low rates of such subfecundity factors as disease and severe malnutrition, the possibility that psychopathology may account for a substantial portion of this subfecundity deserves serious consideration.

There is considerable disagreement concerning the prevalence of psychopathology in primitive and developing societies. Some believe it is common; others feel that it is rare. However, the consensus seems to be that, although the level of psychopathology is considerably lower than in developed societies, it is more common than was previously thought. Consequently, the amount of psychopathology-induced subfecundity is probably also greater than is generally accepted. The following statement by a World Health Organization committee is significant because it aligns itself with the view that psychological factors have a definite role to play in the fecundity of developing societies:

"Congential abnormalities of the female genital tract, endocrine factors, and *psychological* factors causing infertility and preg-

Photo U S National Archives

Charles and Anne Morrow Lindbergh visit Eskimos of Point Barrow, Alaska, in 1931. The social dislocations caused by the intrusion of Western ways upon their simple hunting and fishing society have been followed by severe outbreaks of mental illness among the Eskimo.

nancy wastage are not discussed here since, although they represent some of the main causes of infertility, there is no evidence that they have any increased significance in Africa south of the Sahara" [emphasis added].[30]

In addition, many developing populations are in the process of modernizing, and the rapid sociocultural change and disorganization accompanying this process have led to increased psychopathology. This is particularly true in urban areas where the clash between traditional and modern cultures is sharpest. A recent example of this is provided by the Eskimos, among whom the social dislocations caused by the intrusion of Western ways upon their simple hunting and fishing society have been followed by a severe outbreak of mental illness. Thus, subfecundity due to psychopathology probably assumes far greater importance in transitional societies than in traditional ones. However, little research attention has been directed toward this idea. Kwaku Adadevoh comments on this with respect to Africa:

"Although several psychological variables are of possible relevance as determinants of sub-fertility and infertility, these have received little study despite the rapid sociocultural, political, and economic changes being experienced in most African countries. Impotence induced by fear, lack of emotional compatibility between partners, homosexuality, changing sexual partners and patterns due to widespread use of contraceptive devices, fatalism, marital adjustment problems and changing cultural values could play a role in influencing fertility."[31]

Early researchers believed that psychopathology accounted for a substantial portion of the depopulation of many primitive societies undergoing transition, but later researchers tended to reject this possibility. However, there is no strong evidence *against* the proposition that psychopathology could have contributed materially to depopulation in these societies, in part by depressing fecundity. Demographer Frank Lorimer has concluded that acute social disorganization can, under certain circumstances, lead to the spread of subfecundity and to behavioral patterns prejudicial to fertility, such as infrequent coitus and marital disruption, and that these effects can persist even to the point of population extinction.[32] In such populations, psychopathology is undoubtedly a key link between the acute social disorganization and both subfecundity and behavior that depresses fertility.

The prevalence of psychopathology also varies substantially between subgroups within a population. In the U.S., for example, there are urban/rural, social class, occupational, and racial differences in the amount and type of psychopathology experienced, and psychopathology-induced subfecundity could be expected to vary accordingly. It is interesting to note that both the super-fecund Hutterites and the high-fertility Old Order Amish have very low rates of psychopathology.

Since various psychopathological disorders are concentrated in certain population subgroups, these subgroups may experience rates of psychopathology-induced subfecundity vastly different from the population as a whole. For example, drug abuse has important subfecundity effects, but the proportion of the total U.S. population of reproductive age which abuses drugs is too small (0.7 percent) to affect the country's total fecundity more than slightly. However, the effect could be much more important in the slums of large cities where drug abuse is a major problem, especially among disadvantaged minorities. Consider, for example, the potential effects of drug abuse on the fecundity of young men in Newark, New Jersey, as suggested by this description published in 1977:

"The Newark Addiction Planning and Coordinating Agency estimates that city's hard-core heroin addict population at around 20,000, or about 5% of the city's total population of 380,000. A 5% addiction rate is

serious enough, but only when this figure is put into its proper perspective can we begin to understand its real impact.

"More addicts are males, ranging between the ages of 15 to 35. It is estimated that of Newark's 20,000 hard-core addicts, about 17,000 are young men. According to the 1970 United States Census figures Newark has a total population of 53,000 young males between the ages of 15 and 34. If 17,000 of these 53,000 young men are heroin addicts, it means that one-third of all young men in Newark are heroin addicts."[33]

The authors of this passage consider Newark to be a typical eastern industrial city in terms of urban problems. Thus, although drug addiction may not be prevalent enough to significantly affect the fecundity of the entire U.S. population, it can have a potentially substantial impact on that of sizable urban populations.

The prevalence of psychopathology (and resulting subfecundity) also varies over time. Among U.S. women, for instance, alcoholism, smoking, and illicit drug abuse have all increased considerably over the last several decades. The prevalence of psychosexual disorders such as impotence and frigidity is particularly responsive to social change and, therefore, to variations over time.

In sum, psychopathology is an important cause of population subfecundity, one whose impact varies substantially between populations, between population subgroups, and over time.

Disease

The ability of many diseases to reduce individual fecundity is not disputed. Since high prevalence rates have been recorded for many of these diseases, an impact on the fecundity and fertility of severely affected populations could be anticipated. Indeed, disease is singled out as the main cause of the low fertility and high childlessness in many parts of Africa south of the Sahara and in other populations.

The diseases considered here are infectious diseases, spread by bacteria, viruses, or parasites. Some of the many ways they can affect fecundity are noted with respect to each of the three component parts of fecundity—coital ability, conceptive ability, and the ability to bring a pregnancy to a successful conclusion.

Effect on coital ability

Although many serious diseases, such as tuberculosis and malaria, diminish vigor and reduce libido, few are capable of reducing the actual ability to engage in coitus. However, men with African sleeping sickness (African trypanosomiasis) or leprosy often become impotent. And female coital ability may be reduced by the painful blisters in the genital area which accompany recurrent attacks of genital herpes and make coitus impossible or by scarring of the fallopian tubes after septic (infected), usually back-street, abortions. Painful intercourse is also an almost invariable long-term after-effect of female circumcision (removal of the clitoris and the labia minora), traditionally practiced on girls at puberty and even later and still widespread in Africa in particular.

Infertility

Many diseases dramatically affect conceptive ability by interfering with the production of viable sperm (spermatogenesis) by the male or eggs (ova) by the female, or with their proper transport. Any infection with is accompanied by high fevers may alter spermatogenesis. As noted, in some areas, twice-a-year bouts of malaria can depress spermatogenesis and leave men relatively infertile for two to four months a year. Sperm production can also be reduced or stopped altogether by direct infection of the testes, as happens in certain types of leprosy, and with the parasitic infection of Chagas' disease

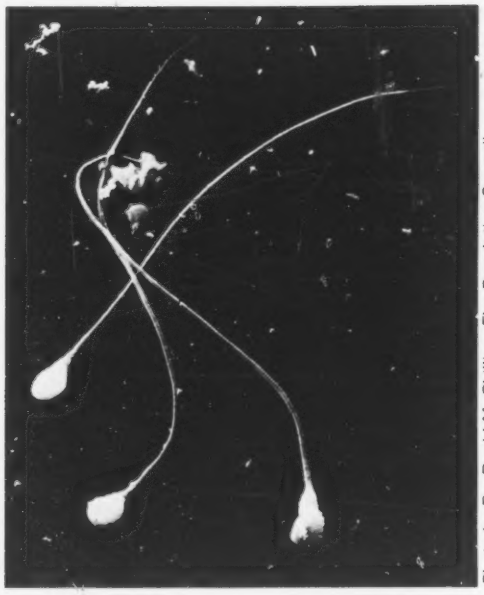


Photo by Dr. David M. Phillips, The Population Council

A scanning electron microphotograph of human sperm. Many infectious diseases can dramatically reduce men's ability to bring about conception by interfering with the production of viable sperm or with their proper transport.

(American trypanosomiasis).

Several diseases can hinder the proper transport of sperm through the epididymis (sperm duct) of the male and of the egg through the fallopian tube of a woman. Gonorrhea is the most widely recognized of these. In its early stages, gonorrhea is more a nuisance than a danger, causing temporary infection in the male's urethra (urine passage) or the female's cervix. But in a certain proportion of cases (1 to 10 percent of females and 1 to 20 percent of males), the infection spreads to the upper genital tract and inflames the fallopian tubes or the epididymis. The resulting scarring can partially or completely block these tubes, depending, in part, on the number of prior tubal infections and how quickly treatment is started. Similarly, when the bacterium of tuberculosis invades the genital tract, nodules are formed along the lining of the epididymis or fallopian tubes. Treatment can eradicate the infection but cannot reverse any tissue damage, and although the tubes may remain open, they are rendered useless. Since gonorrheai and tuberculous infections normally affect both fallopian tubes, sterility is a frequent outcome for women as well as men.

In areas of the world where gonorrhea and genital tuberculosis are both common, it is not easy to determine which (if either) is the cause of any observed sterility since the clinical picture in each disease is very similar. The general tendency has been to overlook genital tuberculosis and ascribe any sterility to the more familiar gonorrhea. As a result, genital tuberculosis is an underrated cause of sterility. It may be particularly important in areas where many women have never conceived (primary sterility) since the disease usually begins before the onset of the childbearing period. By contrast, gonorrhea is contracted during sexual intercourse and women are much more likely to have experienced pregnancy already. In fact, gonorrhea is found even in women with large numbers of children and often in pregnant women. And in some populations with unexpectedly low fertility, there appears to be no correlation between regional rates of gonorrhea and fertility.

Another cause of pelvic inflammation in women is infection after childbirth (postpartum sepsis) or after poorly performed abortion (post-abortal sepsis). The problem bacteria here are found normally in the lower genital tract but tissue damage during childbirth or abortion allows them to enter the upper genital organs. Postpartum and post-abortal sepsis are more likely to be followed by tubal occlusion (blockage) and sterility in developing countries than in developed ones. In developed countries, the infection more often attacks the outside of the tubes, causing a simple thickening of the walls. But in developing countries where women are undernourished and suffer from a number of endemic diseases, any infection is more serious and tubal occlusion is a more frequent outcome.

Female circumcision can also result in sterility by facilitating the spread of infection which leads to the formation of adhesions on the uterus or obstruction of the fallopian tubes.

Two other diseases known to lower conceptive ability are smallpox and filariasis. Disproportionate numbers of infertile men in India have been found to have a history of smallpox; in these men, infertility probably results from obstruction of the epididymis. Filariasis, spread by mosquitoes, is also a cause of tubal obstruction and infertility in men. And although the disease is usually considered a cause of male infertility only, some studies suggest that pelvic infections secondary to filariasis are an important but unrecognized cause of female infertility.

Pregnancy loss

Some of the same diseases which can damage the fallopian tubes and a woman's ability to conceive may also cause pregnancy loss. For example, if the fallopian tube remains open but the lining is distorted or the transport mechanism impaired, the egg may be fertilized, but instead of being carried through the fallopian tube into the uterus, it is trapped in the tube and implants there. Such pregnancies usually end as miscarriages or must be removed surgically. Thus, gonorrheal inflammation, if treated before the fallopian tubes are completely blocked, can lead to a tubal pregnancy. Genital tuberculosis has also been cited as a cause of tubal pregnancy but this is unlikely because even treated victims rarely conceive. Schistosomiasis, a parasitic disease spread by snails which is becoming a serious problem in many parts of the world, is also frequently blamed for tubal pregnancy. However, research shows that this may not be true, for, although the parasite eggs can be deposited in the tubes, they rarely impair the tubes' functioning. One study found no significant difference in the incidence of schistosomal infection of the tubes between women with a tubal pregnancy, women with inflammation of the tubes, and other women.[34] In fact, the exact causes of tubal pregnancy are elusive; in over 50 percent of cases there is no evidence of any tubal inflammatory disease.

Some diseases can bring on pregnancy loss by affecting the unborn fetus. Syphilis is the best known of these. Infection from the mother passes through the placenta to the developing fetus, resulting in miscarriage, stillbirth, or a congenitally syphilitic infant. These disastrous outcomes are effectively limited to the four (and probably the two) years after a woman is first infected with syphilis, before the microorganisms which carry the disease disappear from the woman's blood circulation and burrow into her tissue for a long period of latency. Persons with untreated syphilis cannot be reinfected, so a woman who has had the disease for only a few years or longer has essentially the same chances as anyone else of bearing a live, healthy child. German measles (rubella) caught early in pregnancy can also be transmitted to the fetus with disastrous results, including miscarriage, but the risk is greatest with a woman's first infection although she can be reinfected with the virus several times. Toxoplasmosis, a parasitic disease which can cause brain damage, is also generally thought to result in fetal infection and subsequent pregnancy loss only during a woman's initial infection. But some researchers feel that in some chronic infections the parasites form cysts in the uterus; many fetuses are infected and pregnancy loss occurs repeatedly.[35]

With some diseases, pregnancy loss is the result of a weakened placenta, the spongy mass through which a fetus is nourished. In women with African sleeping sickness, the high rates of pregnancy loss (up to 32 percent) have been attributed to placental infection

with the trypanosome parasite. This is probably also an important cause of miscarriage with Chagas' disease. And invasion of the placenta by *P. falciparum*, the parasite in the most serious type of malaria, is a well-documented cause of low-birth-weight infants and probably contributes to higher rates of perinatal mortality.

Pregnancy loss may also occur if a woman becomes anemic with a disease. Anemia is very common with infection by falciparum malaria, and is noted even in "immune" women in areas where malaria is especially endemic. If the maternal anemia is severe, spontaneous abortion and stillbirth may result.

Many diseases are associated with high fevers and this can be yet another cause of pregnancy loss. In a nonimmune woman, malaria infection results in high levels of parasites in the blood (parasitemia) and, correlated with this, high fevers, high enough to cause miscarriage and stillbirth. Women who live where malaria is hyperendemic are likely to acquire enough immunity to limit the level of parasitemia and fevers are not sufficiently intense to cause pregnancy loss. But in areas where malaria is a common but not a constant feature of life, immunity levels can fail and an infection can result in high fever and pregnancy loss.

Obstetrical complications occur in nearly every woman who has been circumcised and this, too, can cause pregnancy loss. Scarred tissue can leave the vagina so inelastic that passage of the baby is impossible or leaves it so exhausted that vulnerability to infection is increased.

Thus, fecundity is seriously threatened by many diseases (and in Africa by widespread female circumcision). The extent of such diseases varies greatly between populations so that the amount of subfecundity attributable to them is also a population variable. What was their prevalence in historical societies and today in developing and developed societies?

Historical societies

Certainly many of the diseases which cause subfecundity existed in the past. Gonorrhea, which has been known since classical times, is said to have depressed the fertility of historical European populations. And postpartum sepsis has been implicated in the fertility of historical societies. Infection after abortion was also important. For example, induced abortion was legalized in Russia in 1921 following the Bolshevik Revolution, in order to "combat" the "evil" of growing "underground abortion . . . [in which] 50 percent of women are infected . . . and up to 4 percent of them die." (With hard times and scant contraceptive use, abortion totals mounted rapidly and ostensible fear of the effect on Soviet population growth led to the law's restriction in 1936.)[36] As noted, smallpox and genital tuberculosis may also have significantly influenced fertility in numerous historical societies.

Developing societies

Although the developing world is usually characterized as possessing high fertility, there are large areas where fertility levels are low and childlessness reaches up to 50 percent. Since many of the diseases which cause subfecundity are prevalent in these areas, it is likely that disease is a primary reason for the low birth rates.

Although diseases such as African sleeping sickness probably affect fewer than 100,000 persons a year, others, such as filariasis, schistosomiasis, and tuberculosis each count hundreds of millions of victims. Even the little known Chagas' disease affects 35 million persons in South America. And one "conservative estimate" suggests that female circumcision currently affects 20 million women in Sub-Saharan Africa alone.[37]

In many cases, development has

World Bank photo by James Pickerell

This Upper Voltan is more fortunate than many other women of Sub-Saharan Africa whose fecundity has been undermined by rampant infectious disease.

worsened rather than improved the health situation. The Aswan dam in Egypt and other irrigation projects have provided new breeding grounds for the snails which transmit schistosomiasis. Malaria is resurging in many parts of the world because irrigation projects have supplied the Anopheles mosquito with new breeding pools. Meanwhile, spraying programs using DDT, a petrochemical, have become prohibitively expensive with the rise in oil prices, and the parasites are beginning to show resistance to synthetic anti-malarial drugs. As a result, estimates of persons annually infected with malaria now run as high as 600 million.

Gonorrhea has also spread as development increases the contact between cities and villages. In the villages, far from laboratories and good medical care, gonorrhea infections are seldom diagnosed and treated in the early stages and the more serious complications are more common. Another venereal disease, syphilis, though often mentioned as of some significance in developing areas, is probably not terribly important in the tropics. The disease was said to be a major cause of infant death during the 1930s, but it is now believed that kwashiorkor (caused by protein deficiency) and sickle cell disease had been misdiagnosed as congenital syphilis. The high frequency of positive blood tests for syphilis in some areas of Africa may be misleading as other tropical diseases, such as yaws, also give positive reactions.

Infection after childbirth has long been a problem in developing areas. Many women have contracted pelvises, due to malnutrition and perhaps rickets in childhood, which can make labor long and difficult and thus increase the risk of tissue damage and subsequent pelvic infection. The cities of the developing world are now also witnessing tremendous increases in pelvic infection due to self-inflicted or back-street abortion. One study in Kinshasa, Zaire, attributed 95 percent of all obstetric fatalities to hemorrhage or septic complications following induced abortion, which is still illegal in most of Africa.[38] The same study estimated that 20 percent of all women aged ten or over had active or healed pelvic inflammatory disease. These data suggest that, at least in the cities, blockage of the fallopian tubes—the commonest cause of female infertility in developing nations—is due in large measure to septic abortions. In this series, tuberculosis was also seen in one-fifth of cases. In a population with so much tuberculosis, genital tuberculosis could also be a factor in the high prevalence of pelvic inflammatory disease.

Developed societies

Disease is not nearly so important as a cause of subfecundity in developed societies since most serious infectious diseases have been wiped out or brought under control. But some population subgroups, particularly the poor, elude even the extensive health care networks. In the U.S., for example, pockets of tuberculosis are seen in the Southwest among Mexican immigrants. And disadvantaged minorities have higher rates of venereal disease. But with the relaxation in sexual mores and abandonment of the condom (which prevents transmission of venereal disease) in favor of other contraceptive methods, venereal disease is on the increase in all segments of society. In the U.S. alone, three million cases of gonorrhea are reported every year, and a frightening number of young women, up to 100,000 by one estimate, are becoming sterile each year as a result. Non-gonococcal urethritis and cervicitis (NGU/C—inflammation of the urinary passage in males and of the cervix in females) are increasing far faster than gonorrhea, affecting four to nine million Americans each year. While gonorrhea is still predominantly a disease of the poor, NGU/C is seen mostly in sexually active singles from the middle and upper classes. Unfamiliar with NGU/C, many physicians misdiagnose and treat this disease as if it were gonorrhea. This can have serious repercussions, since the organisms which are usually responsible for the infection are insensitive to penicillin, and, if they should ascend to the fallopian tubes, the chances of tubal blockage are three times what they are with gonorrhea.

Genital herpes is also an increasing public health problem. Anywhere from a quarter to one million Americans are infected each year. Since genital herpes is incurable, the effects on fecundity are potentially great. As noted, recurrent attacks of the disease, which occur three or four times a year, may be accompanied by painful blisters which make coitus impossible. And the spontaneous abortion rate among pregnant women with genital herpes is three times that of the general population. The spread of genital herpes has been enhanced not only by a greater frequency of casual sexual encounters but also by the use of oral contraceptives since these increase vaginal secretions which allow the virus to be transmitted more rapidly.

Nutritional Deficiencies

Famine

Famine is the most striking illustration of the power of nutrition to depress fecundity. The first observation of this phenomenon has been attributed to the French historian Jean Meuvret who observed in 1946 that conception rates fell during the famines under Louis XIV. When demographer Louis Henry subsequently established that birth control was rare among the French poorer classes in the 17th and 18th centuries, this fertility drop during periods of famine was seen as due less to contraception and abstinence and more to involuntary biological factors.

Starvation-induced subfecundity has since been noted in several other historical populations. Significant numbers of poor women in Germany during World War I and in France in World War II became subfecund because of food shortages. But the famine in The Netherlands during the winter of 1944-45, the "Dutch Hunger Winter," is probably the best studied. During this last year of World War II most women in Dutch cities were suffering from hunger, not just the poor. Fifty percent became amenorrheic, indicating that ovulation had stopped, and only 30 percent continued to menstruate normally. Conception fell to one-third the normal rate, probably due to lower coital frequency

and delayed marriages as well as infertility. No significant increase in pregnancy loss was noted, however, although children who were gestating at this time had below-normal birth weights.[39]

The importance of psychic stress in such amenorrhea must not be overlooked. For instance, at the end of World War II, 15 percent of the female patients in the hospitals of Dallas, Texas, were amenorrheic, up from one percent at the beginning of the war.[40] Certainly these women were not undernourished, and their amenorrhea was probably due to accumulated anxiety and tension over the outcome of the war and the fate of their loved ones. And the amenorrhea seen so often in the starvation-ridden German concentration camps may also have been caused more by psychic stress and less by undernutrition than might be supposed. Although 54 percent of the 10,000 women who entered Theresienstadt became amenorrheic, they did so within the first three months of imprisonment, before their body stores of nutrients could have been severely depleted. But 18 to 20 months later, after their nutritional status had deteriorated considerably, a great majority of these women began to menstruate normally.

Three hypotheses fit this situation. One is that an acute change in the quality and quantity of food caused the amenorrhea and that gradual accommodation to this nutritional stress resulted in the resumption of menstruation 18 months later. A second hypothesis is that psychic stress, not nutritional stress, was the primary cause of the amenorrhea, and that gradual acceptance of and even resignation to their fate reduced such stress and menstruation returned. But, in fact, the most reasonable hypothesis, and the one specialists subscribe to, is that "war amenorrhea" is the result of multiple stress, both psychological and dietary.

The effects of starvation on the male have not been as extensively studied since they are not quite so evident. It has been noted, however, that starving males experience, successively, loss of libido, decreased sperm counts, loss of sperm motility, and, eventually, the cessation of sperm production.[41]

Chronic malnutrition

As dramatic as these examples are, famine and starvation play only a minor role in human nutritional deficiencies. Far more lives are lost, or at least shortened, by chronic malnutrition, and the effect on population subfecundity is potentially more important. Since malnutrition refers to improper diet of any sort, it describes the overnutrition common in the developed world as well as the inadequate nutrition of the developing world. In the former, overeating and/or the eating of too many salty, fatty, sugar-laden foods contribute to obesity and related diseases such as diabetes and hypertension.

Obesity is very common in the developed world. In the U.S., 10 to 12 percent of children and 35 to 50 percent of middle-aged adults are overweight. Obesity is increasingly being recognized as a cause of subfecundity in men and women. In men, obesity has been implicated as a cause of secondary impotence and of reduced sperm counts. Obese women may be relatively infertile because of a greater frequency of irregular menstruation and amenorrhea. And pregnancy in an obese woman is risky for the fetus, as prolonged labor and pre-eclampsia (a form of high blood pressure) are more common. The association of obesity with pre-eclampsia is somewhat puzzling, however, as this pregnancy complication has also been noted in the hungry world.

Obesity is also an important precipitating factor in two chronic diseases, diabetes and hypertension. Both of these conditions are largely hereditary, but are often unmasked by certain environmental factors such as diet. Diabetes has already been discussed

under genetics as a cause of coital inability, infertility, and pregnancy loss. Hypertension, like diabetes, is more likely to surface in obese persons. Weight loss and a low salt diet often help to lower blood pressure, but proper control usually also requires daily medication, and this medication may initially cause impotence and ejaculatory disorders in some men. Hypertension in pregnant women is a serious matter and carries significant risk for the offspring as well as the mother. As important as these effects are, the impact of diabetes and hypertension on population fecundity is not as great as might be expected since these diseases usually develop toward the end of the reproductive period or later.

Although overnutrition is the primary type of malnutrition in developed nations, undernutrition in significant population subgroups must not be overlooked. In the U.S., for example, chronic undernutrition is seen in poor, minority ethnic groups, Indians living on reservations, migrant workers, and among the aged.[42]

Chronic undernutrition is, of course, most widely observed in developing societies. The nutritional situation varies considerably from region to region. In some areas, there are outright shortages of foods necessary to an adequate diet. In others, diets are adequate but deficiencies develop because parasites such as hookworm compete for essential nutrients, gastro-intestinal infections prevent assimilation of ingested foodstuffs, and repeated, closely-spaced pregnancies and breastfeeding place a continuous nutritional burden on women which does not allow for a period of replenishment.

Malnutrition—whether due to a deficiency of a particular nutrient or of a more general nature—has many effects on fecundity. Specific deficiency diseases such as anemia and pellagra can limit reproductive potential. Iron-defi-

Photo: U.S. Agency for International Development

Waiting to be fed in Bangladesh. Chronic undernutrition jeopardizes the fecundity of hundreds of millions of men and women in the developing world.

ciency anemia, caused either by inadequate intake of iron or by abnormal loss of iron to parasites such as hookworm, is associated with elevated rates of perinatal mortality. In some areas of the world, 5 to 15 percent of adult women are anemic, pregnant women being disproportionately represented because of the demands of the developing fetus for iron. Perinatal mortality is two or three times more frequent in cases of severe maternal anemia. In less severe cases, low birth weight and prematurity are thought to be common pregnancy outcomes, but the many other poor health factors in anemic women make it difficult to be sure that the anemia alone is the cause.

Pellagra, caused by a deficiency of protein and vitamin B, is also seen as a cause of subfecundity. It is endemic in Italy, Romania, and Spain and was quite common in the southern U.S. in the early part of the 20th century. The disease has several fecundity-depressing aspects: skin lesions on the genitals make pellagra victims more susceptible to venereal disease; female victims suffer irregular menstruation and amenorrhea; and pregnancies are complicated and may result in fetal death.

Deficiencies of other vitamins have been suggested as factors in subfecundity with both men and women. Lack of vitamin A, E, or C is believed to suppress sperm production, and spontaneous abortion caused by abnormal uterine bleeding has been attributed to deficiencies of vitamins C, K, and P. However, most of the data to support these hypotheses come from animal studies and any real influence on human reproductive potential is debatable.

Specific deficiency diseases usually occur only in selected groups, particularly infants and young children, and pregnant and breastfeeding women. General undernutrition, however, is much more common and any effects on fecundity are potentially very important. Severe undernutrition, which affects tens of millions of persons worldwide, is associated with amenorrhea and progressive sperm failure, just as is the more serious but fortunately now rare starvation from famine. Less serious undernutrition affects hundreds of millions. In the poor countries of the world, one-half to two-thirds of children are undernourished.

Perhaps the most serious consequence of chronic undernutrition for fecundity is contracted pelvis. For women with this skeletal deformity, labor in childbirth is often prolonged and complicated, and the chances of producing a live baby are severely reduced. Instruments must often be used for the delivery and non-sterile conditions can cause pelvic infection and subsequent sterility.

Undernutrition may also cause delayed menarche and an extended period of adolescent sterility. Chronically undernourished women experience more irregular menstrual cycles without ovulation, and also more pregnancy loss, longer amenorrhea linked with breastfeeding, and a more rapid fecundity decline with age. In undernourished males also, sexual maturation is delayed and fecundity declines more rapidly with age. Exactly how these effects occur is still being investigated and opinions vary. Nevertheless, it is usually thought that the reproductive organs remain responsive to hormonal stimulation and that the problem is at the hypothalamic-pituitary level.

Several of these subfecundity effects are well documented. Many studies have shown nutrition to be an important determinant of age at menarche and at menopause. One U.S. study placed the average age at menarche for well-nourished girls at 12.43 years against 14.45 years for poorly nourished girls. Another in New Guinea recorded menopause as occurring almost four years earlier in malnourished women than in their better-fed counterparts. However, the role of chronic undernutrition in other subfecundity effects is controversial.

There is some disagreement, for ex-

ample, over the importance of undernutrition in pregnancy loss. Many researchers believe that a causal relationship exists. In fact, the large decline in fetal loss in the U.S. after 1940 has been tied to improved nutrition. But physician-demographer Henry Mosley feels there is little evidence for such a link while admitting that the difficulty of studying early pregnancy loss could allow some fetal loss to go undetected.[43] The evidence linking starvation and pregnancy is evenly divided. Pregnancy loss was higher than usual during famines in Biafra and Greece, and twice the normal rate during the Siege of Leningrad in 1942. However, no such effect was reported for the Dutch famine or for the 1974-75 famine in Bangladesh.

Also debated is the effect of a mother's nutritional status on the length of amenorrhea after childbirth—an important determinant of birth intervals and, hence, family size. While many studies show that amenorrhea lasts longer with undernourished women, it may be that nursing patterns—frequency, duration, and intensity of breastfeeding—have more to do with the length of postpartum amenorrhea than how well a woman is fed.

One undisputed, albeit indirect, effect of malnutrition on fecundity is the undernourished's far greater vulnerability to disease, many of them potent causes of subfecundity. Tuberculosis, for example, develops most frequently in the undernourished, and, as noted, genital tuberculosis can lead to irreversible sterility.

Although famine can undoubtedly depress fecundity to such a degree that fertility levels fall, famine is an infrequent occurrence and its demographic importance is minimal. Chronic undernutrition is far more prevalent, but any associated subfecundity is questionable, with the exception of a clear effect on age at menarche and age at menopuase. But since reproductive ability is already low at these extremes of the reproductive period, Mosley argues that it is unlikely that nutrition can alter fecundity to the extent of registering direct effects on fecundity.[44] Indeed, some research at the population level has been unable to show any significant effect on fertility.[45] But other researchers feel that there is every reason to believe that the biological effects of nutrition on fertility are "profound."[46]

Environment

In the demographic literature, the focus in dealing with environmental effects on fecundity has been on natural environmental factors such as heat (climate), light, and altitude, and on the hazards of radiation. Although data show lower conception rates in hot weather, this is probably not the result of diminished fecundity but simply a reflection of lower coital frequency when the thermometer mounts. It has also been shown that temperature is not an important variable in determining age at menarche or menopause. Changes in the length of day and night, although defining the breeding cycle of many animals, have little or no effect on human fecundity. Altitude does, however, affect human reproductivity, the low oxygen tensions at high altitudes resulting in reduced fertility which is readily reversible by migration to lower altitudes.

Radiation

The effects of high-dose radiation on fecundity were demonstrated by the increased incidence of spontaneous abortions and stillbirths among pregnant Japanese women who were near the sites of the atomic bomb explosions at Hiroshima and Nagasaki. Surprisingly, no long-term effects on fecundity have been noted; these women subsequently showed no increased rates of sterility, fetal loss, or defective births. Sperm levels were reduced for men near the center of the blast, but these too re-

turned to normal. This recovery of spermatogenesis has also been observed in nuclear workers accidently exposed to high doses of radiation. Four months after exposure these men were sterile; 21 months later spermatogenesis had returned; and full fertility was present 41 months after initial exposure.

The effects of low-dose radiation, such as medical X-rays, on the developing fetus have been known for some time. But the notion that low doses are harmless to adult tissue is disappearing quickly with reports of cancer among persons X-irradiated for skin and sinus problems and of excess cancer mortality among men overhauling nuclear submarines. Low-dose radiation may also affect fecundity; fertility problems were recorded in the 1950s for shoe salesmen who used a fluoroscope to check the fit of shoes. Because of the increasing use of radioisotopes in medical research and industry, the proliferation of nuclear power plants, the increasing amount of radioactive waste, and the escalating use of medical X-rays, the level of radiation in the environment is growing at an alarming pace, increasing the chances of any negative effects on fecundity. The recent near-explosion of a reactor at the Three Mile Island nuclear plant in Middletown, Pennsylvania, is a sobering example of how the proliferating use of nuclear materials can result in the potential exposure of large numbers of people to low, but not insignificant, amounts of radiation. (The current and planned proliferation of nuclear power reactors in the U.S. is shown in Figure 2 on page 34.)

Toxic chemicals

Radioactive materials are not the only toxic materials accumulating in the environment. Toxic chemicals used in the manufacture of pesticides, herbicides, plastics, and many industrial products are multiplying at a prodigious rate. Seventy thousand chemicals are now widely used and an additional 1,000 are introduced every year. An alarming number of these chemicals are being identified as causing cancer and other serious health problems such as sterility, pregnancy loss, and birth defects. Government regulatory agencies have often been unable to successfully evaluate the safety of a particular chemical, and many health alarms have been sounded by alert citizens.

Men working in the manufacture of the pesticide DBCP asked for fertility tests after noting that no pregnancies were occurring among their wives. Tests showed half the men to be sterile, with zero or low sperm counts. Women in Oregon, noting the high incidence of miscarriage in their community following seasonal spraying with the herbicide 2, 4, 5-T, urged government study of the effects of the chemical. Investigators found that exposed women had spontaneous abortions at three times the normal rate and the Environmental Protection Agency placed an emergency ban on the product and a closely related chemical, Silvex, which is used by homeowners as a weed killer. It is becoming increasingly evident that the health and fecundity of people in industrialized nations are being threatened at the workplace, by the air they breathe, the water they drink, the food they eat, and even by the clothes they wear.

Occupational hazards

A half century ago an English doctor noted that scrotal cancer was much more frequent among chimney sweeps, probably due to prolonged exposure to soot. Since that time many more occupations have been identified as damaging health and fecundity. Anesthesiologists are at a particularly high risk. Women in this profession who work while pregnant have an increased rate of miscarriage, according to studies in the U.S.S.R., Denmark, and the U.S. Other studies have noted higher rates of sterility for all operating-room personnel and an increase in congenital malformations among babies born to women

whose husbands are anesthesiologists.

Men and women whose workplace is contaminated by lead dust are also threatened by high rates of sterility and pregnancy loss. But new federal guidelines to lower the allowable level of lead in factories will offer more protection for the almost one million Americans who are at risk of developing lead poisoning on the job.

A newly recognized occupational hazard involves the manufacture of synthetic estrogen in oral contraceptive plants. Breast enlargement with and without a decrease in sexual drive was noted among male employees, while menstrual abnormalities appeared in female employees. In one plant, unsuccessful pregnancy was 2.5 times higher for persons working in research and development than for administrative personnel.

Increased rates of pregnancy loss have been recorded for women whose husbands work with vinyl chloride, a chemical used in the synthesis of polyvinyl chloride, PVC, a widely-used plastic. Rates of miscarriage and stillbirths among these women doubled after their husbands began working with vinyl choloride.

One of the most startling revelations of an occupational hazard that affects fecundity was the 50 percent rate of sterility among men involved in the manufacture of the pesticide DBCP. The workers were well protected against contamination—coveralls, hoods, and respirators were required as well as an atmosphere of only 1 part of DBCP per million. The results suggest that even minute amounts of DBCP can suppress sperm production. Thus, an effect on farmers, who use the pesticide to kill microscopic worms, and, indeed, on consumers of treated produce, is possible.

Millions threatened

Far more Americans than just chemical workers are threatened by the many

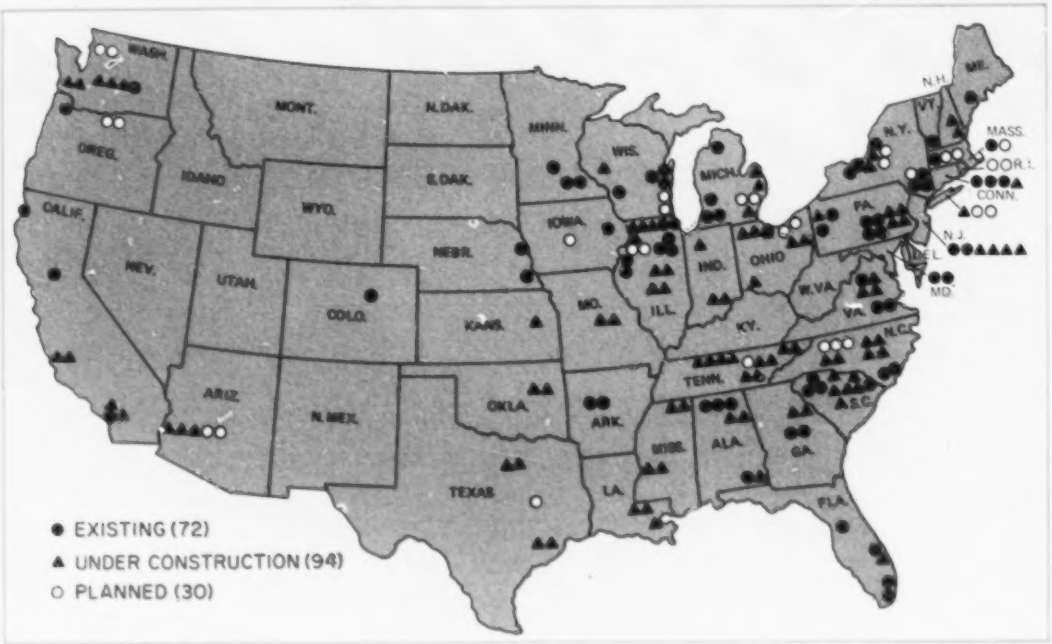
Photo: United Press International

Miscarriages at a rate 50 percent higher than normal have been recorded in the community built on this toxic chemical dump site, near the chemically-contaminated Love Canal at Niagara Falls, New York.

poisonous chemicals that have now found their way into the air, water, and soil. Studies of all families living in towns where PVC is made show a rate of birth defects three times more than normal. PCB, a widely-used industrial chemical, is found in dangerous levels in fresh water fish. High levels of PCB and other toxic chemicals implicated in reproductive failure have also been found in numerous samples of human breast milk.

Much of the environment is being contaminated because of inadequate procedures for the disposal of industrial waste, because many products go into widespread use before all health effects are known, and because of accidents. The first of these conditions may be the most hazardous and most difficult to rectify. Containment and burial proce-

Figure 2. Nuclear Power Reactors in the U.S., January 1979



Source: U.S. Department of Energy

dures that were deemed safe 20 years ago are now recognized as being grossly inadequate. The U.S. countryside is mottled with chemical dump sites that are virtual time bombs—toxic chemicals stored in rusting barrels that can rupture, poisoning an entire community. Attempts to locate these dump sites before there is a catastrophe will often meet with failure, since chemical companies have often subcontracted their waste disposal to "recycling" firms, many of which are no longer in business, their records lost. Thus the incident at Love Canal in New York state, where an entire community was built on a toxic chemical dump site, is probably just the first in a series of such tragic events. The total health effects of the leaking chemicals on the residents of Love Canal will not be known for many years, but already a miscarriage rate 50 percent higher than normal has been recorded.

That chemicals can be widely used before their health effects are known is illustrated by the case of TRIS. In order to comply with a new federal regulation requiring that children's sleepwear be fire-retardant, manufacturers hastily added TRIS to their pajamas. Just as hastily, TRIS-treated clothing was removed from the shelves when further animal tests conclusively demonstrated that the chemical could cause cancer. In addition, there were fears that boys wearing TRIS-treated pajamas could become sterile and develop sperm mutations and testicular abnormalities. Interestingly, TRIS is a chemical cousin to DBCP which caused sterility in male chemical workers.

A tragedy in Michigan in 1976 is an example of how a simple mistake can have serious repercussions on environmental safety. The first sign that something was wrong came when many livestock in the state became ill and died.

After some sophisticated sleuthing, it was found that bags of PBB, a toxic industrial chemical, had been mistaken for a feed additive. Many farm products were contaminated and an estimated 9 million Michiganders were exposed to PBB in varying levels. Farmers were the most heavily contaminated and some farm women reported menstrual disorders. But contaminated food is not limited to the Michigan experience. Almost 14 percent of the meat and poultry sold in U.S. supermarkets may contain illegal residues of chemicals suspected of causing cancer, birth anomalies, and other toxic effects.

The magnitude of the effects of environmental pollution on fecundity can only be guessed. So many hazards are still unidentified, and the total impact of identified hazards may be far greater than is currently observable. What is certain is that ongoing technological development, the introduction of new products, and increasing urbanization and industrialization will all magnify the problem.

Contraceptives and induced abortion

Technological development and scientific advances have created an additional threat to human fecundity. Advanced methods of limiting fertility, for example, may be lowering fecundity as well. A minority of women develop amenorrhea after discontinuing use of oral contraceptives; in some of these women the amenorrhea may persist for years. But the condition nearly always cures itself or is responsive to drug treatment.[47] Pill use has also been linked to the increase in genital herpes since it makes the genital tract more susceptible to inflection with this virus. And in predisposed women, use of the pill may lead to overt diabetes with all the subsequent risks to fecundity.

The intrauterine contraceptive device (IUD) has been linked to some risk of pelvic infection which may cause sterility and disappointment among a few of its users who later hope to bear children.[48] Low-grade pelvic infections are three to nine times as likely to develop in women using an IUD as in sexually active women using another type of contraceptive method. One particularly hazardous type of IUD, the Dalkon Shield, with a complex tail that facilitated the transmission of bacteria from the vagina into the uterus, was withdrawn from the market after several deaths and more than 200 septic spontaneous abortions had been traced to its use.

The damage that "back-street" induced abortion can inflict on a woman's fertility potential has been recognized as long as this ancient method of birth control has been practiced. Now with the increasing number of abortions in countries where restrictive laws have been eased, it appears that even legal abortions carry some risk. Pelvic infection and endometriosis (a condition in which uterine tissue is found elsewhere in the pelvic cavity, such as in the fallopian tubes) are both possible outcomes of legal abortions and both can cause sterility. Preliminary findings from an as yet uncompleted study which traced more than 40,000 U.S. women who had an abortion or a live birth in 1970-71 suggest some increased risk of pregnancy loss following legally induced abortion.[49]

The method used for the abortion probably makes a difference. This is evident from a World Health Organization study which examined the outcome of pregnancies among 1,600 women in eight European cities who had previously had an abortion either by dilatation and curettage (D & C), the "classical" abortion technique for the first three months of pregnancy, or by the newer vacuum aspiration method which reduces the risk of perforating the wall of the uterus. The results suggest that D & C carries an increased risk of mis-

carriage with later pregnancies that vacuum aspiration does not, although prior abortions by vacuum aspiration are associated with slightly more premature and low-birth-weight infants than D & C.[50] The safer vacuum aspiration technique is now by far the preferred method in the U.S., accounting for 84 percent of the estimated 1.2 million legal abortions performed in 1976.[51]

Fecundity Variability Between Populations

Subfecundity factors vary in type and prevalence from population to population, and thus fecundity also varies between populations. If population fecundity is thought of as a continuum, the Hutterites would establish the upper extreme and the population of the Bas-Uele district of Zaire would perhaps represent the lower extreme. Among the latter, subfecundity is rampant, as evidenced by the nearly 50 percent childless rate for women aged 30 to 34 during the 1960s.[52] By contrast, only 2 percent of any one cohort of ever-married Hutterite women are childless. The Hutterites are probably genetically super-fecund, virtually all individuals being the offspring of parents with eight or more children. They are prosperous enough to provide each individual with a nutritionally adequate diet and have a social system that ensures that each person receives it. They avail themselves of two of the world's most advanced health care systems (those of the U.S. and Canada), which minimizes disease and its consequences. They have extraordinarily low rates of psychopathology. And, as members of simple farm communities, they avoid most of the environmental factors that depress fecundity.[53] By contrast, poverty deprives inhabitants of Bas-Uele of proper nutrition and health care; malaria and other subfecundity - producing diseases are endemic and epidemic; and the devastating social forces at work in this rapidly changing society probably ensure substantial rates of psychic stress and other forms of psychopathology. Virtually all other populations experience a degree of fecundity somewhere along the continuum bounded by the high-fecundity Hutterites and the low-fecundity inhabitants of Bas-Uele.

Fecundity of U.S. blacks

One population in which subfecundity has historically played a key role in determining fertility is that of blacks in the U.S. Beginning in the latter part of the 19th century, the black fertility rate declined sharply until the mid-1930s, and then did a turnabout and rose until 1960 (see Figure 3 on page 38). The trend in childlessness was the reverse, rising during the first period and falling during the latter. Population students have long suspected that these trends were due almost entirely to changing health conditions. This "health hypothesis" holds that subfecundity-producing health conditions increased among blacks from 1880 to 1936, leading to widespread involuntary childlessness and subfecundity and a consequent fall in fertility. The subsequent rise in black fertility and decline in childlessness is attributed to a decrease in the prevalence of these conditions. In his important monograph, *Growth of the Black Population*, Reynolds Farley was the first to develop this idea systematically.[54]

George Masnick and the present writer have also concluded that subfecundity was a more significant factor in the U.S. black fertility trend than in that of its white counterpart.[55] In our analysis, however, two other factors are also recognized as important determinants: changes in the prevalence and effectiveness of various birth control

practices, and changes in mate exposure variables such as the proportion of time spent in stable unions. Nevertheless, despite some disagreement on just how influential subfecundity was, there is a clear consensus that it was one of the important causes of the fall in black fertility from 1865 to the mid-1930s.

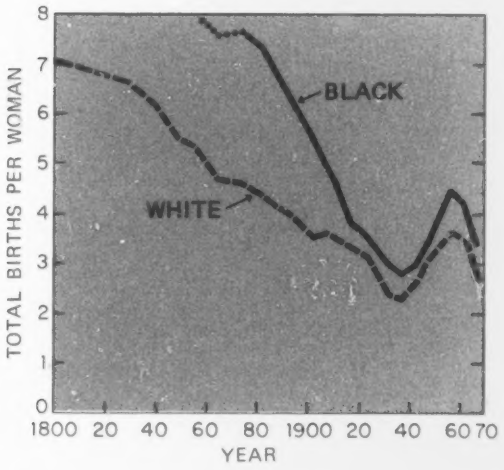
The causes of this subfecundity and their relative importance are still not clear. Early formulations of the health hypothesis focused mainly on the venereal diseases, syphilis and gonorrhea. However, subsequent critiques have shown that their impact on black fertility and childlessness rates was exaggerated.[56] Syphilis has been demoted to a factor of only secondary importance. Gonorrhea retains its status as a primary cause of black subfecundity, but one recognized as having been given undue credit in the past for subfecundity produced by other causes. These underrated causes include genital tuberculosis and postpartum and postabortal infection, general undernutrition and specific deficiency diseases, and psychopathological disorders such as alcoholism and psychic stress.

Take the possible role of genital tuberculosis, for example.[57] TB rates were rising among U.S. blacks as fertility rates were falling. It was only after black TB rates improved substantially that their fertility turned upward. Genital TB is usually a cause of primary sterility, and increasing childlessness was a notable feature of the black fertility decline. Also, childlessness rates were highest and fertility rates lowest in urban centers where TB was most prevalent, and the reverse was true in rural areas. In the South in the early 1900s, childlessness increased and fertility fell in both cities and rural areas. This could have reflected growing interaction between rural and urban areas which helped spread TB more rapidly in rural areas. In addition, economic conditions were deteriorating among blacks in both the city and the countryside, diets were poorer, and the chances for TB to develop thus enhanced. One occupational differential in childlessness, the "mysteriously" high rate among black service workers (domestics and the like), is partly explainable by the fact that many service workers, who have a very high job-related risk of becoming tuberculous, were entering these jobs during their teens when the risk of developing genital TB is greatest. Lastly, secondary sterility (after a woman has had children) can occur with genital TB though not so frequently as primary sterility. This could explain some of the differences in fertility rates observed between tuberculous and nontuberculous black couples in this period. In sum, it appears that genital TB may have been at least as important as venereal disease in causing both the childlessness and reduced family size that led to the

Photo U.S. National Archives

Deteriorating economic and health conditions among U.S. blacks led to widespread involuntary childlessness and subfecundity and a consequent fall in their fertility from 1880 to 1936.

Figure 2. Total Fertility Rates of U.S. Black and White Women, 1800-1969



Source: Ansley Coale and Norfleet Rives, "A Statistical Reconstruction of the Black Population of the United States," *Population Index*, Vol. 39, No. 1 (1973) cover.

downswing in U.S. black birth rates from 1880 to 1936.

The Future

That subfecundity is a serious problem for many couples is well accepted. And many researchers are now convinced that widespread subfecundity is a chief explanation for the relatively low fertility of some presumably non-contracepting populations, such as those in the swath of countries across Central Africa today. In both developing and developed nations, the primary repercussion of subfecundity, especially childlessness, is disappointment for the couples involved. But in some developing nations, where the repercussions are such that entire areas are threatened with depopulation, subfecundity can be a hindrance to further development.

What, then, can, or is, being done to relieve subfecundity? Certainly identification of the causes is a first step; individuals might then be alerted to avoid or protect themselves from specific diseases, environmental assaults, and other conditions which could limit their reproductive potential. In this vein, many people are now avoiding alcohol and other harmful drugs, taking precautions against contracting and spreading venereal diseases, and choosing to live in areas where life is less stressful and environmental pollutants are at a minimum. Even if a particular subfecundity factor cannot be avoided, many protective measures can be taken. Immunization with rubella vaccine protects against an infection with serious complications during pregnancy. Rh-negative mothers can and should be treated after every Rh-positive pregnancy with biological agents that block the formation of antibodies against Rh. And many persons are turning to transcendental meditation, regular exercise, and other approaches to coping successfully with stress.

But for many individuals, especially in developing countries, there is less chance to avoid subfecundity factors or prevent their effects and subfecundity is already a fact. What can be done to allow these persons to have the children they so desperately want? Medical advances in the treatment of subfecundity have been proceeding at a prodigious rate. Forty years ago only 10 percent of subfecund couples could be helped to achieve a pregnancy. Today 40 to 60 percent of subfecund couples can be helped.

Much coital inability stems from psychosexual disorders such as impotence and dyspareunia (painful coitus in women), and the pioneering work in sex therapy of Masters and Johnson, together with more conventional types of psychiatric treatment, have brought tremendous improvements in this area of reproduction.

Psychosexual disorders can also impair male and female conceptive ability, and these treatments have worked well

here also. Hormonal abnormalities also play a role in conceptive defects. Insensitivity of the testes to hormonal stimulation is the reason for at least some previously unexplained cases of low or zero sperm counts, but more research is needed before effective treatment methods can be devised and implemented. But ovulatory failure in women caused by a hormone deficiency is well understood and present treatment methods have been very successful, producing a pregnancy in 35 percent of cases. In the more intractable cases of ovulatory failure, more radical methods of treatment have resulted in multiple pregnancies, some women having produced up to 15 non-viable fetuses at a time. A very recent discovery is that small, benign tumors of the pituitary gland are an important cause of infertility in the some 15 percent of American couples who are involuntarily childless. These tumors secrete a hormone, prolactin, which interferes with the ability of the pituitary to secrete those hormones which stimulate the ovary and the testis. Using new microsurgical techniques, physicians have been able to safely remove these tiny growths, and three of the first ten women to undergo this operation have become pregnant.[58]

Microsurgery also offers new hope to those 8 percent of infertile men and 45 percent of infertile women whose problem is the result of tubal obstruction or other abnormalities. Some of these men and women realize they made an error in judgment and want their vasectomies or tubal ligations reversed. But most suffer from congenital defects or their tubes have been damaged as the result of infections and other pathological processes. In those women whose tubes are missing or so badly damaged that surgical repair is impossible, the only hope for a pregnancy currently rests with the procedure used by Drs. Steptoe and Edwards with Lesley Brown. But the procedure is difficult and the success rate has been low.

Varicocoele, swollen veins in the scrotum, is the prime cause of male infertility, at least in the developed world. This disorder is often cured by relatively simple surgical techniques. Forty-five percent of men operated on for varicocoele go on to become fathers.

The ability of modern medicine to deal with the high-risk pregnancy has increased fetal survival among women with histories of problem pregnancies, hypertension, diabetes, alcohol and drug abuse, and kidney disease. The tremendous improvement in fetal survival among diabetic women whose pregnancies are closely supervised is but one example.

Unfortunately, the promise of some medical and technological advances in alleviating subfecundity has been marred by fears that such advances could be put to insidious uses. The ability of the English team to fertilize a woman's egg outside her body with the sperm of her husband and successfully implant it in her womb has aroused fears of surrogate mothering, cloning, and the like. But such fears are largely unfounded. More concern should perhaps be directed toward making medical advances in every field, including reproduction, more available than they now are to all of the world's peoples. □

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German measles (rubella) face increased risks of spontaneous abortion, but the induced abortions obtained by infected women who fear their offspring might be malformed by this virus account for far greater amounts of "pregnancy wastage." Even inadvertent vaccination of pregnant women with the attenuated virus of German measles, though not conclusively known to cause malformations in the fetus, is a frequent cause of induced abortion. In one series, 50 percent of vaccinated women sought abortions, yet not one of the continued pregnancies ended in congenital rubella. Syphilis is also a good example of a subfecundity factor that can indirectly affect fertility through other intermediate variables. Infected persons, as well as those trying to avoid the disease, often use prophylactic procedures during coitus (most commonly, condoms) that are secondarily contraceptive. The discovery of syphilis during the frequently mandatory premarital blood test may force postponement or even cancellation of marriage. And before antibotics, the prospect of giving birth to a child with congenital syphilis was probably a reason for voluntary abortion. Syphilis is also almost certain proof of one partner's infidelity and undoubtedly increases the frequency of separation and divorce.

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